



# MECHANICS 12





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# **Mechanics 12**

## **Module 1**

# **INTRODUCTION TO ENGINES AND SHOP PRACTISES**



**Distance  
Learning**

**Alberta**  
EDUCATION

Mechanics 12  
Student Module  
Lessons 1-20 and Practical Activities Booklet  
Alberta Distance Learning Centre  
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## INTRODUCTION

Mechanics 12 is an introductory course in the career field of mechanics. The course is designed to introduce the student to power sources and methods of transmission. Students will study the construction and operation of the motor vehicle systems and apply information learned to analyze and repair minor machine problems.

The topics covered include: career field study, safety, shop practices, automobile care and ownership, power sources, engine support systems, and the transmission of power. There is no textbook for the Mechanics 12 course. All information is contained in the lessons themselves. General references relating to mechanics would be helpful to the student who wants to advance their skill and knowledge beyond the scope of this course.

### 1. Non-liability of the School

While extreme care has been taken in the preparation of the practical assignments, the Alberta Correspondence School cannot be responsible for any injury which may result while working on the practical assignments. You must be willing to accept full responsibility for your own actions in this regard.

### 2. General Instructions

- (a) When you receive the course, take it apart carefully so that the pages will remain unturned. If you open the book firmly in the middle, the staples will separate and the book will come apart. You can then remove the whole pages without tearing them. Use rings to keep the pages together in the right order.
- (b) Try to form good habits of study. After you have read the assigned pages, read through the exercises. See how well you can answer them. If you have difficulty with any of the exercises, you may find it necessary to read the lesson material a second time.
- (c) Before you start an exercise, be sure that you have read the instructions thoroughly so that you understand them.
- (d) It is good practice to keep a record of the time you spend on your work. This course constitutes the work of an entire school year. It contains twenty lessons. There are forty weeks in a full school year. If you are on a 10 month school year you need to submit an average of one lesson every two weeks. If you are on a semester system you should submit a lesson every week. You can send a lesson as soon as you have finished it. That way it will get marked faster and you will get it back sooner.
- (e) When a lesson is returned to you, study the corrections and comments made by the teacher. Find out what parts of your work have been good and what parts could be improved. Try to benefit from the corrections. Similar mistakes in successive lessons indicate that the student is not giving sufficient attention to the corrections.
- (f) Avoid using abbreviations, ditto marks, and the symbol '&' for the conjunction 'and' in your written answers. All words should be written in full.

- (g) Before sending a lesson for correction, check to be sure that all exercises are completed, or at least attempted. Do not leave any questions blank or with just a ? written in. They will be returned with an 'F'. Please do all questions.
- (h) Please use dark ink for all written exercises. Do not write with pencil or colored ink. Avoid writing with pencil first and then going over the work with ink.
- (i) When submitting your lessons, send only those pages on which there are written answers. Pages containing only teaching notes should not be submitted.

### 3. Practical Work Assignments

This portion of the course involves doing practical work on a vehicle. In order to complete it, **you will require the supervision of someone knowledgeable in the field of vehicle maintenance and repair** (such as a qualified journeyman mechanic or a certified mechanics or automotives teacher). The supervisor must be willing to supervise your work, to outline safe procedures and tool use, and to demonstrate desired methods. Also, the supervisor must give a signed evaluation of your work.

You will require access to a vehicle for this section. Use the same vehicle throughout the practical work activity. One of the activities involves doing an engine oil change. Try to arrange the practical work so the oil change comes at the correct time or mileage period for the vehicle.

### 4. Video Tape

A video tape, *An Oil Change, The Easy Way*, is available on loan to students who wish to view it. The video portrays the proper procedure to follow when changing the oil in a vehicle. (An oil change is one of the requirements in the "Practical Work Assignments" section of the course.) An application form for the tape can be found at the beginning of lesson 10.

**EVALUATION PROCEDURE**

All students registered in Mechanics 12 who have completed at least **eighteen** lessons plus the practical work assignment will have their course mark evaluated as indicated below. The evaluation is out of 100 percent.

Practical Work	20 percent
Lessons	20 percent
Final Exam	<u>60 percent</u>
Total	100 percent

**NOTE:** If you score less than 40% on the final test, your final mark in the course will be based entirely on the final test score.

### ADVANCE NOTICE CONCERNING TESTING AND COURSE EVALUATION

1. In order to be recommended for credits in Mechanics 12, you are required to write a supervised test set by the Alberta Distance Learning Centre before registration expires. 40% of the final mark will be based on your course work, as evaluated by a teacher of the Alberta Distance Learning Centre. 60% of the final mark will be based on your final test. If you score less than 50% on the final test, your final mark in the course will be based entirely on the final test score. Appeal papers will be available to students who request them and whose registration has not expired.

2. (a) **Classroom students**

Classroom students are those who are in attendance in school in Alberta and who are supplementing their school programs by taking one or more correspondence courses.

A student attending school does not submit an application for the final test. Test papers are sent automatically to the principal in January and June for writing before the end of the semester or at the end of August for writing during the first week of September for summer school students. At least **eighteen satisfactory lessons**, out of the twenty to be submitted, must be received by the Alberta Distance Learning Centre before a test paper is mailed to the principal. As well, the practical work assignment **must** be submitted before the test is written, since you will lose marks for the course work portion if only eighteen or nineteen lessons are submitted.

The principal is in charge of scheduling final tests and all questions about scheduling should be directed to the principal.

If a test is not written before the expiry date of registration, the course is considered incomplete for the school year which the student registered.

- (b) **Non-classroom students**

Non-classroom students are those who are studying exclusively by correspondence and are not registered in any subjects in an Alberta classroom.

To obtain course credits, non-classroom students must complete all required lessons and write the final test before the expiry date of registration. Information about expiry dates is given in the Information Bulletin which a student receives before filing an application for a correspondence course.

The application for the final test is sent out when the corrected Lesson 14 is returned to the student. The student submits the completed application with Lesson 18. The test is sent out after **eighteen satisfactory lessons**, out of twenty to be submitted, have been received by the Alberta Distance Learning Centre. As well, the practical work assignment **must** be submitted before the test is written, since you will lose marks for the course work portion if only eighteen or nineteen lessons are submitted.

If a test is not written before registration expires, the course is considered incomplete for the school year during which the student registered.

**NOTE:** For the purpose of writing final tests, students who live outside Alberta come under the same regulations as those in category (b).

# **DICTIONARY & SI METRIC**



## A DICTIONARY OF TERMS COMMON TO THE MECHANICAL TRADE

**ABDC** — after bottom dead center — used to mean the piston is just starting on the upward portion of a stroke so that the rod is past perpendicular.

**abrasion** — wearing or rubbing away, as the action of sandpaper on wood.

**abrasive** — tending to wear or rub away, as the action of sandpaper.

**absolute zero** — state in which no heat nor molecular movement is present, believed to be  $-273.16^{\circ}\text{C}$ .

**AC** — alternating current — the current which continually reverses its normal direction of flow.

**accelerator** — a foot pedal which through mechanical linkage controls a throttle valve in the carburetor and therefore the engine speed.

**accelerator pump** — a small pump inside a carburetor which sprays fuel into the venturi as soon as the accelerator is pressed.

**accumulator piston** — a unit designed to assist the servo to activate brake bands in an automatic transmission.

**acetylene** — the gas commonly used in oxy-acetylene welding and cutting operations.

**acid** — in automobiles — the active component of electrolyte which is ( $\text{H}_2\text{SO}_4$  sulphuric acid).

**Ackerman principle** — a design which means that a line intersecting each kingpin and tie rod would intersect at or near the differential. Results in toe out on turns.

**active material** — in the storage battery, this refers to the peroxide of lead (brown) in the positive plates and the metallic lead (gray) in the negative plates upon which the  $\text{H}_2\text{SO}_4$  acts.

**additive** — something used to change an original product in an attempt to make it better.

**advance** — to change the timing of the spark so that it occurs earlier or more degrees before top dead center.

**air** — natural gas containing approximately  $\frac{4}{5}$  nitrogen,  $\frac{1}{5}$  oxygen with some carbonic gas.

**air bleed** — an opening into a gasoline passage through which air can pass into the gasoline as it moves on its way through the passage.

**air cleaner** — a device used for filtering and removing dust and foreign particles from the air.

**air cooled** — something which uses only the circulation of air around it to keep it from overheating.

**air-cooled engine** — an engine that is cooled by the passage of air around the cylinders as opposed to other using liquid coolants.

**air foil** — device similar to the small wing mounted on racing cars, dragsters to assist in high speed and/or stability — mounted horizontally.

**air-fuel ratio** — the ratio by mass of the air to gasoline mixture used in the engine.

**air gap** — usually refers to the space between the side electrode and center electrode of a spark plug.

**air horn** — the fresh air inlet of the carburetor which the air cleaner is attached.

**air-injection system** — a system which forces air into the exhaust manifold or thermal reactor (whichever one is used) so that the unburned hydrocarbons and carbon monoxide can be further combusted before entering the atmosphere.

**air pollution** — contamination of earth's atmosphere by various natural and man-made pollutants such as smoke, gases, dust, etc.

**air pressure** — the measured pressure of an air mass or volume of air. i.e. the pressure in a tire, the pressure discharge of an air pump, the pressure of air on a portion of the earth due to the atmosphere. At sea level the pressure is 101.325 kPa due to the atmosphere, usually used as 101 kPa.

**alignment** — an adjustment to a line or to bring into proper perspective to each other.

**Allen wrench** — a hexagonal wrench used to fit into a recessed hexagonal hole, usually used for set screws.

**allowance** — how much larger or smaller a part may be and still work satisfactorily.

**alloy** — a mixture of different metals. For instance, solder which is a mixture of lead and tin.

**alternator** — that part of the electrical system which is able to convert mechanical energy into electrical energy for use in the electrical systems.

**aluminum** — a metal noted for its lightness but in automotive use it is usually alloyed with other metals to increase its strength, etc. but still referred to as aluminum.

**ammeter** — a meter for measuring the amount of electrical current flowing in a circuit.

**amperage** — the amount of current flowing in a circuit, measured in amperes symbol to be used is a capital A. Most modern alternators put out 30A - 55A at 15 V (volt).

**ampere** — a unit of electric current. The exact definition is "That constant electric current which, if maintained in two straight parallel conductors of infinite length of negligible circular cross-section, and placed 1 m apart in vacuum, would produce between these conductors a force equal to  $2 \times 10^{-7}$  N/m."

**ampere-hour** — the measure of the capacity of a storage battery - for example, if 2 A can flow for 0.5 h then the rating would be 1 A-h.

**anode** — in an electrical cell this is the positive post.

**antibackfire valve** — a valve used in air injection reaction (exhaust emission control) systems to prevent backfiring during the period immediately following a sudden deceleration.

**anti-freeze** — a substance which when added to water will lower its freezing point below the normal of  $0^{\circ}\text{C}$ .

**antifriction bearing** — type of bearing in which moving parts are in rolling contact. There are three distinct types - ball, roller or tapered roller.

**antiknock** — in an engine fuel, this refers to the property in the fuel which opposes knocking in the engine during combustion.

**antiperculator** — device used for venting vapors from the main discharge tube, or wall, of a carburetor.

**arc welding** — a method of utilizing the heat of an electric current jumping an air gap to provide the heat for melting the metal.

**arcing** — the name given to what electricity will do if at some point in a circuit there is a break in which the two sides are close enough for the current to jump across from one to the other.

**armature** — a mechanical part moved by magnetism, or through a magnetic field, to produce an electrical current.

**asbestos** — a natural heat and fire resisting material widely used for brake linings, clutch faces. Any place where heat of friction could be very high.

**atdc** — after top dead center - means that the piston has passed its highest point of travel and is somewhere starting its downward movement.

**atmospheric pressure** — the measure of the atmosphere due to its downward force on the earth. At sea level this is 101.325 kPa, usually used as 101 kPa for convenience of usage.

**atom** — a unit of matter composed of protons, electrons and neutrons.

**automatic choke** — a choke valve that is operated automatically according to the engine temperature.

**automatic transmission** — a transmission that shifts to different gears automatically depending on load conditions, engine speed, etc.

**axle - full-floating** — bar used to drive the rear wheels but does not actually hold them on the vehicle or support the load. (Large trucks).

**axle - semi floating** — See semi-floating axle definition.

**axle ratio** — the relationship or ratio between the number of times the drive shaft must rotate to revolve the axle shafts one turn.

**backfire (exhaust)** — passage of unburned fuel mixture into the exhaust system where it is then ignited causing an explosion.

**backfire (intake)** — igniting of the fuel mixture before it reaches the cylinders causing an explosion in the intake system.

**backlash** — the amount of free motion in a mechanical system.

**back pressure** — refers to a resistance to flow of the exhaust gases through the exhaust system, see baffle.

**bad shocks** — refers to shock absorbers which no longer soften the impact of bumps, and reduce sway of the vehicle. For safety, shocks should be checked for damage, wear and/or fluid leaks at least twice a year.

**baffle** — an obstruction built into a system which will slow down or divert the flow of gases, liquids, sounds, etc. Causes a back pressure.

**ball bearing** (antifriction) — a bearing consisting of an inner and outer race of hardened steel, separated by a series of hardened steel balls.

**ball check valve** — a valve consisting of a ball and seat. Fluid can pass in one direction only; if it attempts to flow the other way the ball closes down on its seat.

**ball joint** — flexible joint utilizing a ball and socket type of construction also called a ball stud.

**ball-peen hammer** — a hammer for metal work that has a ball on the top of the head instead of claws as on a carpenter's hammer.

**ball stud** — also called a ball joint. It is a bolt with a ball head mainly used in steering systems.

**barrel** — that part of an air horn where the throttle valve is located.

**battery** — a number of electro-chemical cells connected together in one case to give a specified number of volts.

**battery charging** — the process of reversing the procedure in a battery by passing an electrical current through the battery in the opposite way to which it is drawn off.

**battery terminals** — those external posts of the battery to which connection is made to connect the battery into a circuit.

**BBDC** — before bottom dead center — a term applied when the piston has just about reached the bottom point of its travel in the cylinder.

**BDC** — bottom dead center — that point when a piston is at the extreme lowest point it reaches when travelling in the cylinders and the piston connecting rod is parallel with the cylinder walls.

**bead** — usually refers to the steel wire reinforced edge of a tire which engages the rim when mounted.

**bearing** — the mounting part in which a journal, pivot or the like turns or moves with minimum wear and friction.

**bearing caps** — the cover that bolts down solidly to hold the bearing in place.

**bearing clearance** — the amount of space left between a shaft and the bearing when proper torque is applied to the mounting bolts. The space is left to allow passage of a lubricating film of oil.

**bell housing** — the enclosure around the flywheel and clutch or torque converter at the rear of the engine.

**bellows** — a device which shortens and lengthens like an accordion, usually used as a control in the cooling system thermostat.

**belted-bias tire** — a tire in which the plies are laid on the bias, criss-crossing each other, with a circumferential belt on top of them. The rubber tread is then vulcanized on top of the belt and plies.

**Bendix drive** — a cranking motor drive unit that uncouples the pinion gear and flywheel ring gear automatically as engine speed increases.

**bevel gear** — a gear in which the teeth are cut in a cone shape such as found in axle end gears. Transmits motion at an angle.

**benzol** — a by-product of coke manufacture which has been used as an engine fuel.

**bias-ply tire** — a tire in which the plies are laid on the bias, criss-crossing each other and the tread is then vulcanized to these plies.

**bleeding** — the process by which air is removed from a hydraulic system, by bleeding off part of the fluid as steady pressure is applied to work out any air bubbles trapped in the system.

**block** — that part of the engine which forms the major case in which the cylinders are located.

**blow-by** — refers to a leakage from the compression chamber of a cylinder past the rings into the crankcase.

**boiling point** — that temperature at which a liquid becomes a gas - 100°C for H<sub>2</sub>O (water) at atmospheric pressure.

**bonded lining** — a brake lining which is attached to the shoe by an adhesive rather than by rivets.

**booster** — often used with reference to a mechanical or hydraulic device attached to brake or steering systems to reduce physical effort of the operator.

**bore** — the name given to the diameter of a hole. i.e. cylinder bore, bushing bore, shaft bore all are referring to the diameter of the related hole.

**bottled gas** — LPG (liquified petroleum gas). A gas compressed into strong metal tanks. The gas when confined in a tank under pressure becomes a liquid.

**brake - disc type** — braking system that uses a disc between two linings rather than shoes and a drum. This type of brake system is very resistant to brake fade.

**brake drums** — the metal casings which the brake shoes operate against when stopping the vehicle.

**brake fade** — reduction of braking power due to excessive usage which results in overheating - the drums expand and less friction results from a reduction in shoe contact with the drums.

**brake fluid** — a special fluid which is used in the hydraulic braking systems. It has many special properties, it is: non compressible, non injurious to rubber, impervious to temperature changes.

**brake flushing** — performed when brake system repairs are made. Using air pressure or hydraulic fluid under pressure at the master cylinder the new lines are all blown clear and new fluid used when system is reassembled.

**brake lines** — the tubes and hoses connecting the units of a braking system together. (usually rolled steel tube or special flex lines where required)

**brake lining** — a material with a suitable coefficient of friction which is attached to shoes and contacts the brake drums to retard movement of the vehicle.

**brake - parking** — mechanically connected to rear wheel brakes or to a special brake band in drive train - usually only retards movement in the forward direction effectively.

**brakes - power** — an attachment to the hydraulic brake system at the master cylinder which utilizes engine vacuum to reduce operator pressure on the brake pedal while increasing actual fluid pressure delivered.

**brake shoe** — the carrier to which the lining is attached and which carries the lining into contact with the brake drums when the brakes are activated - on conventional drum type brakes there are two shoes per wheel.

**brazing** — the joining together of metal by the use of a material with a very high melting point such as brass or bronze.

**breaker arm** — the movable arm upon which one of the breaker points is affixed.

**breaker points (ignition)** — a pair of points, one of which is movable, that are opened and closed to control the current in the primary circuit.

**break-in** — the process of using something in a very specific manner so as to obtain a desirable fit between the surfaces of new or reconditioned parts.

**broach** — the process of bringing a metal surface to a desired shape by forcing a multi-edged cutting tool across the surface.

**brush** — name given to a block of conducting substance, usually carbon, which rests against a rotating ring or commutator to form a continuous electric circuit.

**btdc** — before top dead center - when referring to the position of the piston in the cylinder.

**buckling** — a warping or bending used in conjunction with the plates of a battery.

**burnish** — to smooth or polish by use of a sliding tool under pressure.

**bushing** — a sleeve placed in a bore to serve as a bearing surface for a rotating shaft.

**butane** — a gas which is liquid under pressure and used as a vehicle fuel. It is often combined with propane.

**butterfly valve** — a valve in the carburetor that is so named simply because of its resemblance to the insect of the same name. Also called a choke.

**by-pass** — an alternate path to get to the same end point.

**bypass filter** — a type of oil filter in which only some of the oil is filtered while the remainder goes directly to the engine parts.

**bypass valve** — a valve that can open to allow a fluid, etc. to pass through an alternate channel from its normal route.

**cables** — stranded conductors, usually insulated and used for major electrical connections such as the “live” connector to the battery.

**cadmium-tip tester** — a battery tester with cadmium tip that are inserted into the electrolyte of adjacent cells to determine battery condition more accurately than with the use of a hydrometer.

**caliper (inside, outside)** — a measuring tool that can be set to accurately measure a shaft, bore, etc.

**cam** — a device that controls or alters motion - for example the ignition-distributor breaker cam, which, in rotating, causes contact points to open and close. Cam of the camshaft which operates valves.

**cam lobe** — the protruding section of a camshaft which pushes on the movable member in contact with it.

**cam ground** — refers to the fact that pistons are slightly oval when cool and expand to their round shape upon heating.

**camber** — tilting of the wheels away from the vertical; when tilt is outward from the vehicle the camber is said to be positive.

**camshaft** — the shaft in the engine that has a series of cams for operating the valve mechanisms. It is driven by the crankshaft and usually in turn also drives the distributor, oil pump and fuel pump.

**capacitance** — property of a condenser that permits it to receive and retain an electrical charge.

**carbon** — a common non-metallic element which is an excellent conductor of electricity. It is the hard black substance which forms in and on the areas of the combustion chamber from the burning of petroleum products.

**carbon dioxide** —  $\text{CO}_2$  a gas resulting from the burning of fuel.

**carbon monoxide** — CO another gas resulting from the burning of fuel but this one is very poisonous as well as being odorless. It increases with the decrease of complete combustion.

**carburetor** — the device in the fuel system that mixes the air and gasoline in the proportion required to suit the engine operating conditions.

**carburetor “icing”** — a term used to describe the formation of ice on the throttle plate during atmospheric conditions which are fairly cold and quite humid.

**caster** — tipping of the top of a kingpin forward or backward from the vertical. Toward the rear of the vehicle is classed as the positive caster direction.

**catalytic converter** — a device in the exhaust system to convert harmful gases into harmless gases.

**cathode** — the name given to the negative pole of any electrical cell.

**cell** — a unit with positive and negative plates capable of producing about 2 V so a 12 V battery requires 6 cells, etc.

**cell connector** — the strap which joins the positive post of one cell to the negative post of the next cell in the battery.

**Celsius** — the temperature scale used in conjunction with the metric system where  $100^\circ\text{C}$  is the boiling point of water while  $0^\circ\text{C}$  is the freezing point.

**center of gravity** — that point where all mass of an object could be considered to have its focal point. For example, for a wheel this would be the center of the hub.

**centrifugal advance** — ignition spark advance which results from the engine speed.

**centrifugal clutch** — a clutch that utilizes centrifugal force to expand a friction device on a driving shaft until it can contact a drum on a driven shaft to propel it.

**charge** — passing a current backwards through a battery to reactivate the potential of the battery.

**charge rate** — the number of amperes entering the battery per period of time. This must be relative to the size of the battery cells.

**chassis** — normally used in reference to the complete vehicle without the body and fenders included.

**check valve** — a valve that operates to check or prevent excessive pressure rise or other undesirable action. A valve that allows flow in one direction only also is included.

**chemical compound** — a combination of any two or more chemical elements joined together like water ( $H_2O$ ) which is a combination of 2 parts hydrogen for each part of oxygen in the compound.

**chemical element** — gaseous, liquid or solid matter which cannot be divided into simpler forms, like helium.

**chemical explosive engine** — compact source of high power for a short time. Combustion gases from burning propellants drive a turbine harnessed to do the required work.

**choke** — located in the carburetor, a device that closes off the flow of air through the air horn, producing a partial vacuum in the air horn for greater fuel delivery resulting in a richer mixture. Classed as a butterfly valve.

**choke stove** — a compartment around the exhaust manifold that directs heat to the automatic choke device.

**circuit (electrical)** — consists of a power source, a power using device and the wires that connect the source to the using unit and then back to the source.

**circuit breaker** — breaks the path in an electrical circuit when an overload occurs. Differs from a fuse in that the breaker can be re-set rather than replaced as a fuse is.

**clearance** — that space which is left between moving parts so that they may move and be lubricated from each other.

**closed crankcase ventilation** — the fumes of the crankcase **cannot** escape to the atmosphere but are channeled through the carburetor via the PCV valve and returned.

**clutch** — a mechanism placed in the power train that is used to connect and disconnect the transmission and drive wheels from the power plant when it is so desired.

**coil** — device installed in the ignition circuit to step up the battery voltage sufficient to fire the plugs.

**cold rate** — a battery rating calculated by how many minutes a battery can deliver 300 A at  $32^\circ\text{C}$  before the cell voltage drops below 1.0 V.

**collapsed piston** — a piston whose skirt diameter has been reduced and deformed due to excessive heat and forces in the engine.

**combustion** — the rapid burning of the air-fuel mixture in the upper portion of the cylinder called the

**commutator** — a cylindrical area at one end of an armature which consists of copper bars separated by mica insulators. It forms the rotating connector between the armature and the brushes.

**compression ratio** — that ratio that is found by a comparison of the cylinder volume at tdc as compared to that at bdc.

**compression rings** — the upper ring or rings on a piston, designed to hold the compression in the cylinders and prevent blow-by into the crankcase.

**compression stroke** — the piston stroke from bdc to tdc when both valves are closed and the air-fuel mixture is compressed in preparation for ignition.

**condensation** — the reverse of evaporation. The change of state of a gas to a liquid.

**condenser (capacitor)** — a device in the ignition system connected across the points to reduce arcing by providing a storage place for the electricity when the points open.

**connecting rod** — the linkage which connects the pistons to the crankshaft.

**cooling system** — the system used for removing the excess heat from the engine. They are of two types - air cooled and liquid cooled.

**contraction** — (thermal) the reduction in size of an object when it is cooled.

**convection** — the transfer of heat from one object to another via air currents when the two objects are not in physical contact.

**crankcase** — the lower section of an engine which holds the oil and in which the crankshaft rotates.

**crankshaft** — the main shaft of the engine which is the major component to which all the connecting rods and hence the pistons are connected.

**cranking motor** — an electric motor used for turning over the engine when starting it. Also called a starter.

**crude oil** — petroleum in its raw state as it is found in nature.

**current** — the actual flow of electrons through a conductor.

**cycle** — in an engine this refers to the completion of the series of events required for a piston to go through all stages required for it to convert the chemical energy to mechanical energy and be ready to start again.

**cylinder** — a tubular structure. In the engine it is the structure in which the piston moves up and down.

**cylinder block** — the main framework of the engine to which the other engine parts are attached.

**cylinder head** — the upper section of the engine which attaches to the cylinder block.

**cylinder sleeve** — the replaceable tube which attaches to the cylinder block.

**DC** — direct current. Different from ac in that the dc flows one way and one way only. All batteries are dc whereas all 'house' power is ac.

**dead axle** — an axle which is stationary and only the wheels on the end rotate. The type found on trailers, etc.

**De Dion axle** — rear drive wheels are mounted on dead axles and differential is bolted to the frame - drive force comes through universally mounted drive axles.

**detergent** — a chemical which when added to oil produces such characteristics as sludge control, non-foaming, suspension of engine deposits, etc.

**detonation** — when the fuel-air mixture burns too fast and virtually explodes causing engine knock.

**dial gauge** — instrument that operates like a micrometer except that it has a needle which registers across a dial face.

**diaphragm** — membrane stretched across an area between two compartments, used in fuel pumps, vacuum pumps, etc.

**Diesel Engine** — internal combustion engine named after its inventor Dr. Rudolph Diesel. This engine burns diesel oil and fires through heat of compression rather than spark plugs.

**dieseling** — name given to the problem of an engine that continues to run after the key is turned off. Usually one cause is hot build ups of carbon which keep igniting the gas.

**differential** — the mechanism in the center of the rear housing which transmits the power from the drive shaft through gears to the axles and yet allows the wheels to turn at different rates - which is necessary to be able to turn a corner.

**diffuser** — a device or design feature that slows the velocity of incoming air while increasing the pressure.

**diode** — a unit with the characteristic of allowing current flow in one direction only and thereby can be used to convert ac to dc where required.

**dipstick** — metal rod which passes into the oil sump and allows a person to measure the quantity of oil contained in the system.

**direct drive** — when engine crankshaft and drive shaft are revolving at the same speed, such as when a 1:1 ratio high gear is engaged.

**discharge** — refers to the slowly deteriorating potential of a battery as electrical current is being drawn off.

**disc brakes** — a form of brakes that use a circular disk between two flat shoes, brake fade in this type of brake system is very low.

**displacement** — the total volume of air removed when the piston travels from bdc to tdc. Found by taking the volume of the cylinder with the piston at bdc and subtracting the volume at tdc.

**distributor** — a unit of the ignition system that makes and breaks the primary circuit to ensure that the high voltage goes to the correct spark plug at the proper time in the cycle.

**drive line** — all the parts required to transmit the power from the transmission to the differential.

**drive shaft** — the connecting shaft between the transmission and the differential shafts.

**drum brakes** — a system of braking which uses curved shoes which press against the inner surface of a circular cylinder to which the wheels are attached.

**dual-brake system** — one in which there are two separate hydraulic system connected to one pedal but supplying rear wheels and front wheels independent from each other.

**dynamic balance** — wheel must be revolving to check dynamic balance and is in balance when the center line of the mass is in the same plane as the center line of the wheel.

**dynamometer** — a machine for measuring the power produced by an engine at the output shaft.

**egr** — exhaust gas recirculator - that sends part of the exhaust back through the intakes to reburn it and thus reduce emissions of NOx.

**electrolyte** — name given to the acid water mixture used in a battery.

**electro-magnet** — a coil of wire, usually with an iron core, which produces magnetism as electric current is passed through the coil.

**emery cloth** — a cloth backing with emery abrasive cemented to its surface, used to clean and polish metals.

**engine** — as applies to an automobile - a device used to convert heat energy into useful mechanical energy.

**engine displacement** — the sum of the displacement of one cylinder multiplied by the total number of cylinders in the engine.

**ethylene glycol** — the chemical solution most used today as an anti-freeze in cooling systems.

**exhaust manifold** — those connecting pipes between the exhaust valve port of the engine and the exhaust pipe.

**exhaust pipe** — that portion of the exhaust system between the exhaust manifold and the muffler.

**exhaust valve** — that valve which allows the burned gases to be removed from the cylinder.

**external combustion engine** — burns the fuel outside of the basic engine and the burning is continuous.

**fan** — a device used to draw or blow an extra quantity of air through an area.

**feeler gauge** — a finely machined metal strip used to determine the thickness of a clearance between two parts.

**ferrous metal** — those metals which contain iron or steel and are subject to rust.

**f-head engine** — an engine having one valve in the head and the other in the block.

**filter** — there are usually three or more on every car they are used to remove impurities from air, oil, gas, etc.

**flat head** — an engine with all valves mounted in the block.

**float bowl** — the part of the carburetor that acts as the reservoir for a supply of gasoline and contains the float mechanism for controlling entry of the fuel.

**flooding** — the condition where an oversupply of unburned gasoline has reached the cylinders due to a mixture which is too rich or excessive pumping of the accelerator before the engine is actually running.

**fluid coupling** — also known as fluid drive, consisting of two vaned rotating elements held close to each other. Rotation is imparted to the driven member by the driving member through the resistance of fluid.

**flywheel** — a form of harmonic balancer attached to the rear of the crankshaft to provide inertia to keep the crankshaft turning smoothly between power strokes.

**fossil fuels** — all fuels ultimately derived from living things and chemically classed as hydrocarbons (coal, oils, natural gas etc.)

**four-stroke cycle engine** — an engine which has four stages to a cycle - intake, compression, power, exhaust and in which the crankshaft must make two complete revolutions to fire each piston once.

**free electrons** — those electrons in outer orbits of an atom that have the capability of absorbing enough energy to be broken away from the atom.

**free piston engine** — power plant with two pistons freely moving back and forth in a casing with a multi-diameter cylinder. Exploding gases of combustion are directed to a turbine which powers a compressor that transmits power to drive the wheels.

**friction bearing** — bearings made of bronze, babbitt, etc. and often called shells. These bearings have sliding contact with moving surfaces, and have no moving parts in themselves.

**fuel cell** — an electric power plant that converts chemical energy of a fuel directly into a continuous flow of electricity.

**fuel injection** — a fuel supply system that does not incorporate a carburetor but instead the fuel is sprayed directly into each cylinder at the correct time.

**fuel mixture** — a mixture of gasoline and air which usually averages about 16 parts air to one part of gasoline.

**fuel pump** — a device in the fuel system to get the fuel from the tank to the engine without requiring the tank to be higher than the engine.

**full floating axle** — a drive axle construction where the axle does **not** carry any of the mass of the vehicle - normally found in trucks and heavier equipment.

**full flow oil filter** — the type of filter that has all of the engine oil passing through it for purification on its way from the sump to the engine parts.

**fuse** — a protective device in electrical circuits to break the flow of current if it becomes excessive - must be replaced once it has performed this function.

**gasket** — a material put between two surfaces to prevent leakage, insures a proper seal.

**gasoline** — name given to a hydrocarbon product of petroleum suitable for engine fuel.

**gas turbine** — an internal combustion engine where the pressure of combustion forces the turbine blades to turn.

**gear ratio** — the relationship obtained when one compares the number of revolutions made by a driving gear as compared to the revolutions of a driven gear.

**generator** — an electromagnetic device which changes mechanical energy to electrical energy to serve the electrical system.

**grease** — a lubrication compound to which thickening agents have been added.

**ground** — the terminal at the battery which is usually connected to the frame or engine by a strap - often uncovered and usually connected to the negative battery terminal.

**gum (fuel system)** — oxidized portions of the fuel that form deposits in the fuel system and on engine parts.

**harmonic balancer** — a device attached to the front of a crankshaft to reduce the torsional vibrations - also called a vibration damper and located as an interior part of the front v-belt drive pulley.

**heat riser valve** — thermostatically controlled valve in the exhaust manifold used to channel hot air around the intake manifold to preheat the gas-air mixture.

**heat sink** — an area of an electrical device used to aid in dissipation of heat to the atmosphere.

**helical gear** — a gear that has the teeth cut at an angle to center line of the gear.

**herring bone gear** — a pair of helical gears operating together so that the angle between the teeth forms a "V".

**high-test gas** — a term which implies that this gasoline has a very high octane rating.

**high tension** — usually refers to the secondary circuit of the ignition system which carries the high voltage output of the coil.

**hotchkiss drive** — a driving axle design wherein the axle torque is absorbed by the chassis springs.

**hydraulic** — pertains to the science of using fluids in mechanical operations.

**hydraulic brakes** — a braking system that uses the pressure of hydraulic fluid in the activation of the friction plates against the revolving wheels to retard motion.

**hydraulic clutch** — usually used in clutch activation where such clutch is so remote from the driver area as to make mechanical linkage impractical.

**hydraulic lifters** — a valve lifter which through the use of fluid maintains a zero clearance to reduce valve noise.

**hydraulic steering** — the use of hydraulic pressure to reduce driver effort in the steering of heavier vehicles.

**hydrocarbon** — a compound made up entirely of hydrogen and carbon, which includes petroleum products.

**hydrometer** — a measuring device to determine relative density - especially useful in the determination of battery condition.

**geothermal power** — tapping heat from the earth's crust and directing it to a power plant to generate electricity or use it to heat buildings.

**governor** — a device used to control speed or position of some part - may be mechanical, electrical or hydraulic in operation.

**hypoid gear** — a gear set up whereby one gear is so cut as to operate away from the center line of the other gear - typical is the pinion-ring gear of the differential.

**I-head engine** — an engine that has both valves in the head.

**independent suspension** — there is no direct connection between two wheels and one can move up or down without affecting the other one.

**in-line engine** — an engine in which all of the cylinders are in a single straight row.

**intake manifold** — the enclosure which connects the base of a carburetor with the various intake ports for distribution of the fuel-air mixture.

**intake valve** — the valve which opens and closes the intake port to the flow of the fuel-air mixture.

**internal combustion engine** — an engine which burns the fuel within itself to develop power.

**journal** — that area of a shaft so machined as to accept a friction bearing.

**king pin** — the steel pin in which the steering knuckle pivots.

**king pin inclination** — the tipping inwards of the tops of the king pins to place the steering axis nearer the center line of the tire-road contact area.

**knocking** — sound made by an engine when the fuel burns too rapidly or unevenly, also, noise made by movement of parts in a loose, damaged or worn bearing.

**lands** — that metal which is used to separate grooves such as the raised areas between ring grooves of a piston.

**leaf spring** — a suspension spring set up whereby the springs are assembled of thin, flat steel sections.

**I-head engine** — an engine in which both valves are located in the block and on the same side of the cylinder.

**limited slip differential** — one design which transmits torque to a wheel that is not slipping to increase traction of a vehicle.

**live axle** — a driving axle that is firmly affixed to the driven wheels.

**lpg** — Liquified Petroleum Gas - must be kept under pressure or at low temperatures to remain in the liquid state.

**lubricant** — any material placed between surfaces to reduce friction - usually a petroleum product.

**magneto** — old time form of coil but differs in that it does **not** require an outside source such as a battery to enable it to generate high voltage for the spark plugs.

**main bearings** — the bearings which support the crankshaft.

**master cylinder** — that part of the braking system that acts as the main reservoir and pressure generating area.

**mechanical brakes** — those brakes that are operated solely by mechanical linkages.

**micrometer** — a measuring device to accurately tell the inside or outside measure of a precision part.

**muffler** — a device in the exhaust system which slows down the speed of the escaping gases thereby reducing the noise such gases make as they escape into the atmosphere.

**needle bearing** — those bearings which are cylindrical and have a very small diameter in relation to their length.

**needle valve** — a screw type valve with a long tapering point which operates in a jet and controls the size of the opening.

**negative terminal** — usually the smaller of the two parts of the battery and sometimes marked with a minus sign.

**Newton's Law** — for every action there is an equal and opposite reaction.

**nitrogen oxide** — NO<sub>x</sub> - in the combustion process nitrogen from the air combines with oxygen.

**non-ferrous metals** — those metals that do not contain any iron or steel and are therefore not subject to rusting.

**octane rating** — the rating of a gasoline that indicates its ability to resist detonation.

**ohm** — the measure of resistance in an electrical circuit. ( $\Omega$ )

**oil filter** — that unit which strains the oil to remove impurities from it.

**oil gallery** — pipes or drilled passages used to transport lubricating oil from one area to another.

**oil pump** — that device of the lubricating system driven by the camshaft to force the oil into circulation through the engine.

**oil sump** — the storage reservoir for oil and the catch basin for heavy sludge material.

**overrunning clutch** — a clutch mechanism which will drive in one direction only if driving torque is removed, reversed or overcome the clutch slips.

**oversteer** — the tendency for a car negotiating a turn, to turn more sharply than the driver intends.

**parking brake** — mechanically operated brake attached to rear wheels or a special drum on the driveshaft to retard movement of the vehicle.

**Pascal's Law** — "when pressure is exerted on a confined liquid it is transmitted undiminished to all points of the liquid" this occurs almost instantaneously.

**pcv** — positive crankcase ventilation. A system whereby the fumes of the crankcase do **not** escape to the atmosphere but are returned to be reburned.

**penetrating oil** — a special oil which will aid in the releasing of rusted parts.

**petroleum** — raw crude oil from which a multitude of products are manufactured.

**Phillips head screw** — a screw with two crossed slots as compared to a regular screw of a single slot.

**piston** — the portion of an engine that forms the base of the combustion chamber and is the first moving part to receive the thrust of the burning fuel mixture.

**piston boss** — built up area around the piston pin holes to reinforce them.

**piston pin** — a steel pin which attaches the piston to the connecting rod.

**piston rings** — rings which fit around the upper end of the piston to form seals for compression, oil, etc. — usually three or more of them.

**planetary gear set** — gear set of an outer unit with an internal ring gear and an internal sun gear between which there are two or three planet gears which operate in conjunction with each other.

**plastigage** — a plastic material in strips that is inserted between two parts. When the parts are tightened together and then separated the amount of spread of the plastigage gives the amount of clearance between the two parts.

**preignition** — fuel charge being ignited before the proper time.

**pressure cap** — a special cap so designed as to maintain the contents up to a predetermined pressure but not above it.

**primary circuit** — that circuit of wiring and units in which the low voltage of the ignition system flows.

**rack and pinion steering** — a system where a pinion gear on the end of the steering wheel shaft operates against a long rack of teeth.

**radial engine** — an engine so formed that the crankshaft is in the center with the pistons forming a circle around it.

**radial-bias tire** — a tire in which the plies are laid on perpendicular to the rim with a circumferential belt on top to which the rubber tread is then vulcanized. Never mix tires on your car, use the same type as sets.

**radiator** — the unit of the cooling system that acts as a reservoir and transfers the accumulated heat to the atmosphere.

**reciprocating motion** — motion back and forth such as that performed by pistons.

**rectifier** — a device to change ac to dc current. One type is found on alternators and uses diodes to perform this function.

**regulator** — a device used to control something like generator voltage, current output, pressure of a gas, etc.

**retard** — to set something back like retarding the spark in an ignition system so that the spark occurs later.

**riding the clutch** — a very bad habit in which a person allows part of his foot to be in contact with the clutch pedal when it is not being used.

**ring gap** — the amount of space between the ends of a ring when mounted on a piston to allow for expansion.

**ring ridge** — a ridge that forms at the highest point travel and **must** be removed before trying to take a piston out of an engine block.

**rotary engine** — a stationary crankshaft with the pistons rotating around it, or with rotors as found in the Wankel engine.

**rpm** — revolutions per minute - the speed with which something is turning by counting the revolutions.

**SAE** — Society of Automotive Engineers.

**sealed beam headlights** — a headlight unit which is non-repairable and must be replaced as an entity.

**sealed bearing** — one that was lubricated with a life time lubricant and then sealed at the factory - if any problems arise it must be replaced.

**secondary circuit** — the high voltage parts of the ignition system.

**semi-floating axle** — the type of axle most common to the modern auto - outer end is attached to the wheel, supports the mass of the car but the inner end "floats" in the differential.

**servo action** — brakes so constructed that the one end of the primary shoe bears against the end of the secondary shoe increasing the force of action.

**shock absorber** — an oil filled device used to control spring oscillation in a suspension system.

**sodium valve** — a valve in which the stem has been partially filled with metallic sodium to help speed the transfer of heat from the valve, down the stem and into the block.

**solenoid** — an electrically operated magnetic device used to operate other units.

**spark** — the bridging or jumping across a gap between two electrodes causes this as in a spark plug.

**spark plug** — the device attached to the engine and protruding into the cylinder to provide for the ignition of the fuel mixture.

**spider gears** — small gears between the differential gears and the axle gears.

**spiral bevel gears** — widely used in the differentials and consist of a ring and pinion both having gears tapered so as to operate on an angle to the center line of the pinion shaft.

**spongy pedal** — where hydraulics are concerned - this is an indication of air bubbles in the system.

**spur gear** — a gear in which the teeth are cut parallel to the shaft.

**stabilizer bar** — a transverse mounted spring steel bar that controls and minimizes body lean on corners.

**starting motor** — the unit in the electrical system that converts electrical energy to mechanical energy to turn over the engine to initiate starting.

**static balance** — when a body has a uniformly distributed mass around its axis it will be in static balance. This means that the body will stay in a position it is placed in without rotating on its axis.

**steering system** — the mechanism which allows the operator to control the direction of movement of the vehicle.

**Stirling Engine** — a type of internal combustion engine in which the piston is moved by the changing pressure of a working gas that is alternately heated and cooled.

**storage battery** — that part of the electrical system which stores electrical energy as chemical energy.

**sun gear** — the center gear around which the planetary gears revolve.

**super charger** — a method of forcing air into cylinders to gain more power.

**synchronesh transmission** — a transmission which has synchronizers that move to change gear ratios while the gears themselves are fixed to the shafts - this reduces "gear grinding."

**tail pipe** — that portion of the exhaust system from the muffler to the rear of the vehicle.

**TDC** — top dead center - when the piston is at its exact highest point of travel in the cylinder.

**thermal reactor** — a chamber in the exhaust manifold where air is pumped to continue the burning of the fuel to reduce pollutants.

**thermostat** — a device to control the temperature at which something operates.

**throttle valve** — the lower valve of a carburetor which controls the amount of fuel-air mixture getting to the cylinders.

**throw out bearing** — the bearing in the clutch used to move the pressure away from the clutch to disengage it.

**thrust bearing** — one of the main bearings of the crankshaft which has side flanges to prevent excessive endwise movement of the crankshaft.

**timing marks** — usually found in the vibration damper and aid in setting the firing point of the spark plugs.

**toe-in** — the amount of difference between the distance across the front of the front wheels compared to the distance across the back of the front wheels. The fronts are slightly closer together.

**tolerance** — amount of variation permitted from a specified measurement.

**torque** — the turning or twisting effort and is measured in Newtons-metres.

**torque converter** — a device in the power train between the flywheel and automatic transmission consisting of three or more rotating members. It transmits power through a fluid providing varying drive ratios with speed reduction and increasing torque.

**transaxle** — a drive set up where the differential and the transmission are combined into a single unit.

**transistor ignition** — use of transistors to regulate the voltages greatly increases the life of the components.

**transmission - automatic** — gear changing is done by the vehicle regulated by speed, load, etc., the operator chooses the maximum gear setting only and a clutch is optional and usually left out.

**transmission - standard** — all shifting from one gear to another is done by the operator - this type must have a clutch.

**two-stroke cycle engine** — one which requires one complete revolution of the crankshaft to fire each piston once.

**unit body** — auto construction in which the body itself is used as the frame of the vehicle.

**universal joint** — a flexible joint which allows one shaft to drive another at an angle to the first one.

**unsprung weight** — all parts of the vehicle **not** supported by the suspension system.

**vacuum** — an area in which pressure is lower than that in surrounding areas - will always equalize if allowed to.

**valve** — a device to open and close a port.

**valve lap** — period of time when two valves are open at the same time like in the cylinder when the piston is at tdc between the exhaust stroke and the intake stroke.

**venturi** — an hour-glass shaped restriction in a carburetor in which there is an increase in the speed of flow and a corresponding increase in vacuum (decrease in pressure).

**vibration damper** — attached to the front of a crankshaft to reduce torsional vibration.

**viscosity** — the resistance to flow that a liquid has. The thicker the fluid the greater the viscosity.

**volatility** — the tendency for a fluid to evaporate rapidly at certain temperatures, the lower the temperature at which a fluid will evaporate into a gas, then the more volatile it is.

**voltage** — a measurement of electrical force that will move a current of 1 A through a resistance of 1  $\Omega$  is 1 V.

**Wankel Engine** — a rotary type engine in which one, two or more three lobbed rotors turn excentrically in an oval chamber.

**water jacket** — the space around cylinder sleeves, etc. through which the coolant passes.

**water pump** — that device of the cooling system which pumps the coolant into circulation through the system.

**welding** — the process of fusing metals together using heat.

**wheel balancer** — a device used to check mounted tires to see if they are in static and dynamic balance - some operate with the wheel on the car, others the wheel must be removed.

**wheel cylinders** — these are mini-cylinders of the hydraulic braking system which reverse the process of the master cylinder. At the master cylinder, mechanical energy is imparted to the fluid and at the wheel cylinder the fluid energy imparts mechanical energy to move the braking friction plates.

**windshield wiper** — used to keep a windshield clean during rain or snow and activated by engine vacuum or electricity.

**worm gear** — a coarse spiral gear cut on a shaft. One is found in the steering gear box.

**wrench** — general name given to any tool used to tighten, or loosen nuts or bolts.

**wrist pin** — another name for the pin which holds the piston to the top of the connecting rod.

**GUIDE  
TO  
SI  
(METRIC SYSTEM)**



## SI (The Latest Version of the Metric System)

**The Change to Metric:** Through the centuries, many measurement systems have developed evolving from numerous origins, convenient customs, and local adaptations. Most systems have lacked rational structure. The Imperial system using the yard, quart, and pound — is one such conglomeration of poorly related units.

About 200 years ago, France decided to bring order out of her chaotic measures and the metric system was born. Although strongly opposed at first, this new system proved effective and gained popularity, so much so, that over 90% of the world's population now lives in countries that have adopted or are changing to the metric system.

**Various Versions of Metric Systems:** There have been several metric systems, but each new version has added more metric units, causing unnecessary congestion. To make matters worse, in some applications there has been a mixture of both Imperial and metric units, and something had to be done to clean house.

**The Latest Version of the Metric System:** In 1960 the International System of Units was established as a result of a long series of international discussions. This modernized metric system, called SI, from the French name, *Le Systeme International d'Unites*, is now, as a general world trend, replacing all former systems of measurement, including former versions of the metric system. Canada has decided to convert to SI.

Many European nations are making the change to SI — a change from former metric practice. The United Kingdom, Australia, New Zealand, South Africa, and others are adopting SI, while countries such as India, China, and Japan are updating their metric practice to conform to SI. In the United States, major industries are tooling up for metric conversion, and their choice, too, is SI.

It is SI, not S.I. — omit the periods.

It is just called SI not the “SI system,” since the “S” stands for the word “system.”

**SI is Similar but Different:** SI includes familiar metric units such as the metre and kilogram. There are, however, a number of changes from former metric systems. For instance, the centigrade temperature scale is called the Celsius (pronounced sell-see-us) scale when used for general purposes. This is a change in name only, so that 20°C, formerly read as “twenty degrees centigrade,” is now read as “twenty degrees Celsius.” There is no change in the scale, only in the name. Water still freezes at 0°C and boils at 100°C (degrees Celsius, that is). This kind of change is not difficult for those who are familiar with older metric systems.

**Numbers Moulded Metrics:** The metric system was based on the convenience of the decimal number system. Units are related by factors such as 10, 100, and 1000. This makes computation in the metric system much simpler than that with Imperial measures. A great deal of the arithmetic merely involves the shifting of the decimal, without tedious calculations.

This course is written using SI units exclusively. The table of units below is a reference guide so you can easily understand what these units mean.

PLEASE: Try to think **SI Metric** and use these metric measures whenever possible.

**Table of Prefixes**

Prefix	Symbol	Meaning	Multiplier
tera	T	one trillion	1 000 000 000 000 = $10^{12}$
giga	G	one billion	1 000 000 000 = $10^9$
*mega	M	one million	1 000 000 = $10^6$
*kilo	k	one thousand	1 000 = $10^3$
hecto	h	one hundred	100 = $10^2$
deca	da	ten	10 = $10^1$
*		one	1 = $10^0$
deci	d	one tenth of a	0.1 = $10^{-1}$
*centi	c	one hundredth of a	0.01 = $10^{-2}$
*milli	m	one thousandth of a	0.001 = $10^{-3}$
micro	$\mu$	one millionth of a	0.000 001 = $10^{-6}$
nano	n	one billionth of a	0.000 000 001 = $10^{-9}$
pico	p	one trillionth of a	0.000 000 000 001 = $10^{-12}$
femto	f	one quadrillionth of a	0.000 000 000 000 001 = $10^{-15}$
atto	a	one quintillionth of a	0.000 000 000 000 000 001 = $10^{-18}$

**\* most commonly used**

Unit	Symbol	Meaning	Example
terametre	Tm	$10^{12}$ m	Distance from sun to Saturn = 1.4 Tm
gigametre	Gm	$10^9$ m	About 3 times distance from earth to moon
megametre	Mm	$10^6$ m	Distance from Calgary to northern Alberta border
kilometre	km	$10^3$ m	Length of brisk 10-minute walk
metre	m	1 m	Height of 3-drawer filing cabinet
millimetre	mm	$10^{-3}$ m	Thickness of a dime
micrometre	$\mu$ m	$10^{-6}$ m	Size of bacteria
nanometre	nm	$10^{-9}$ m	Length of oil molecule
picometre	pm	$10^{-12}$ m	Wavelength of gamma rays
femtometre	fm	$10^{-15}$ m	Diameter of a proton
attometre	am	$10^{-18}$ m	???

#### TABLE OF SI UNITS AND NON-SI UNITS PERMITTED FOR USE WITH SI

The information in the following tables is in the order of most probable frequency of use. So units that would be used frequently are put first, and units less frequently toward the last. The conversion factors are to be used **only if** you are reading a book or shop manual that has Imperial units. It is recommended that the student start thinking **entirely metric**, and **not even think about the Imperial units at all!** Use metric measurements in your daily life **exclusively** so it becomes a matter of habit. Be modern and up-to-date! Use SI, and encourage your friends to use it too!

QUANTITY	NAME	SYMBOL	NOTES
length	millimetre centimetre metre kilometre	mm cm m km	A Volkswagen is about 4 m long.
area	square centimetre square metre	cm <sup>2</sup> m <sup>2</sup>	
volume	cubic centimetre cubic metre millilitre litre	cm <sup>3</sup> m <sup>3</sup> mL L	1 cm by 1 cm by 1 cm  1000 mL = 1 L 1 L is the volume of a cube 10 cm by 10 cm by 10 cm.
mass	gram kilogram milligram tonne	g kg mg t	1 t is 1 000 kg, this is about the mass of a Volkswagen.
temperature	degree Celsius	°C	A comfortable room has a temperature of 20°C.
time	hour minute second	h min s	
numeric dating			In SI dates are expressed in this <b>exact</b> order: YEAR-MONTH-DAY.  The month is not written out.  <b>Example:</b> handwritten 1986-09-08, typed 1986 09 08

QUANTITY	NAME	SYMBOL	NOTES
speed	kilometre per hour metres per second metres per hour	km/h m/s m/h	A good highway cruising speed would be 100 km/h.
acceleration	metres per second per second	m/s <sup>2</sup>	
gasoline consumption	litres per one hundred kilometres	L/100 km	We are likely to express gas consumption of cars in litres per hundred kilometres, that is, the amount of gasoline it takes for the car to travel 100 km. For instance, a large car may consume gas at 20 L/100 km, while a smaller car may only require about 8 L/100 km. The lower the number of litres, the less gas you consume. This way of stating fuel consumption is prevalent in Europe and other metric areas of the world.
pressure	pascal kilopascal	Pa kPa	The atmospheric pressure is about 100 kPa.
power	watt kilowatt	W kW	A lawnmower motor has a power of about 2 kW.
force	newton	N	The newton is roughly the force required by your hand when supporting 2 golf balls.
electric current	ampere	A	
electric potential, potential difference, electromotive force	volt	V	
resistance	ohm	Ω	

QUANTITY	NAME	SYMBOL	NOTES
rotational frequency	revolutions per minute	$\text{min}^{-1}$	An LP record has a rotational frequency of 33 $\text{min}^{-1}$ , also written as r/min.
energy, work	joule	J	
moment of force, torque	newton metre	$\text{N}\cdot\text{m}$	
density	kilograms per cubic metre	$\text{kg}/\text{m}^3$	
relative density			The terms <i>specific weight</i> and <i>specific density</i> should be replaced by the term <i>relative density</i> . Mercury has a relative density of 13.6, meaning that it is 13.6 times as dense as water. Water is implied as the reference substance for liquids and solids, and air the reference for gases, unless otherwise indicated.
capacitance	microfarad farad	$\mu\text{F}$ F	
electrical charge	coulomb	C	One coulomb is the charge transported in 1 s by a current of 1 A.
electric flux	coulomb	C	
magnetic field strength	ampere per metre	A/m	

## RULES FOR WRITING SI

1. The symbols are always printed in Roman (upright) type, irrespective of the type face used in the rest of the text.
2. Symbols are never pluralized: 45 g (not 45 gs)
3. Never use a period after a symbol, except when the symbol occurs at the end of a sentence. This is done because SI symbols are *symbols* they are **not** abbreviations.
4. Symbols should usually be used and unit names not mixed with symbols.  
Example: 10 kg (preferred), ten kilograms (accepted), never 10 kilograms.
5. Always use a full space between the quantity and the symbol: 45 g (not 45g).  
Exception: For Celsius temperatures the degree sign occupies the space. 32°C (not 32° C or 32 °C)
6. Decimal fractions are generally preferred to common fractions.
7. A zero is placed to the left of the decimal marker if there is no other digit to the left.  
Example: 0.25
8. Symbols are written in lowercase, except when the unit is derived from a proper name: m for metre; s for second; but N for newton; A for ampere; degree Celsius °C is the only one to be upper case in both name and symbol.  
  
Exception: L (capital L) is the symbol for litre.  
  
Symbols for prefixes are shown in lowercase except for those that are **greater** than “kilo.”  
Example: kW (kilowatt) but MW (megawatt)
9. Prefixes are printed in Roman (upright) type without spacing between the prefix and the unit symbol: kg for kilogram, km for kilometre.  
  
Only one prefix is applied at one time to a given unit: megagram or tonne, **not** kilokilogram.
10. Use spaces to separate long lines of digits into easily readable blocks of three digits with respect to the decimal marker: 32 453.246 072 5.  
Exception: A space is optional with a four-digit number: 1 234 or 1234
11. Multiplication of Units in symbolic form is indicated by a dot at mid-letter height between the symbols.  
  
A decimal fraction is indicated by means of a decimal marker on the line, and at present, in Canada, the marker is usually a point positioned in line with the base of the associated numeral.  
  
**Note:** You must never use a dot between numerals to represent multiplication. Any dot you use between numerals will be assumed to be a decimal point.

12. Compound symbols formed by dividing units contains a solidus (/) to indicate the division.  
Example: km/h (kilometres per hour)      r/min (revolutions per minute)
13. The solidus, as a symbol of division, must not be repeated in the same expression unless ambiguity is removed by the use of brackets.  
Example: (m/s)/s is acceptable  $\text{m/s}^2$  is preferable
14. Division by a unit may be shown by means of a negative exponent. In such cases the dot must also be used to avoid misunderstanding.  
Example:  $\text{m}\cdot\text{s}^{-1}$  (metre per second)
15. When a unit is formed by division, the prefix, if any, should be attached to a unit in the numerator.  
Example: km/s **not** m/ms  
  
Exception: When the base unit "kilogram" appears in the denominator.  
Example: MJ/kg is preferred to kJ/g.
16. Exponents are used with symbols for units that are squared or cubed.  
Example:  $\text{m}^2$        $\text{cm}^3$
17. Symbols should not be used to start a sentence.
18. In general, only one unit should be used to express a measured quantity.  
Example: 1.15 m is preferred to 1 m 15 cm.
19. In general, in the expression of any quantity, a prefix should be chosen so that the numerical value lies between 0.1 and 1000. However, when similar quantities are compared, it is better to use the same prefix for all items even though some values may fall outside the 0.1 to 1000 range.
20. A dot must not be used as a multiplier between numerals.  
Example:  $5\times 7$  **not**  $5\cdot 7$
21. In the expression of numbers over ten, digits are preferred to fully spelled out words.  
Example: 28 m

# ***MECHANICS 12***

**MODULE ONE**

**INTRODUCTION TO ENGINES  
AND  
SHOP PRACTISES**



**A LESSON RECORD FORM MUST BE COMPLETED FOR EVERY LESSON  
SUBMITTED FOR CORRECTION, AS ILLUSTRATED BELOW**

A Lesson Record form with the **correct** label attached **must** be enclosed with **every lesson** submitted for correction, as illustrated below.

Correct use of these labels will ensure prompt processing and grading of your lessons.

The enclosed **Lesson Labels** must be checked for spelling and address details.

Please advise the Alberta Distance Learning Centre promptly of any changes in name, address, school, or any other details and we will issue a revised set of labels. Your file number is permanently assigned and **must** be included on all correspondence with the Alberta Distance Learning Centre. If the proper label and Lesson Record Form is not attached to each lesson as indicated it will delay your lessons being processed and credited to you.

Lesson labels are to be attached to the **lesson record forms** in the space provided for student name and address.

Check carefully to ensure that the **subject name, module number and lesson number** on each label corresponds exactly with the lesson you are submitting.

Labels are to be **peeled** off waxed backing paper and **stuck** on the lesson record form.

Only **one** label is to be placed on each lesson.

**LESSON RECORD FORM**

FOR STUDENT USE ONLY		FOR A.D.L.C. USE ONLY	
<div style="border: 1px solid black; padding: 5px; margin-bottom: 5px;"> Date Lesson Submitted   </div> <div style="border: 1px solid black; padding: 5px;"> Time Spent on Lesson   </div>	<div style="border: 1px solid black; padding: 5px; margin-bottom: 5px;"> (If label is missing or incorrect)  File Number _____  </div> <div style="border: 1px solid black; padding: 5px;"> Lesson Number _____  </div>	<div style="border: 1px solid black; padding: 5px; margin-bottom: 5px;"> Assigned Teacher: _____  </div> <div style="border: 1px solid black; padding: 5px; margin-bottom: 5px;"> Lesson Grading: _____  </div> <div style="border: 1px solid black; padding: 5px; margin-bottom: 5px;"> Additional Grading E/R/P Code: _____  </div> <div style="border: 1px solid black; padding: 5px; margin-bottom: 5px;"> Mark: _____  </div> <div style="border: 1px solid black; padding: 5px; margin-bottom: 5px;"> Graded by: _____  </div> <div style="border: 1px solid black; padding: 5px; margin-bottom: 5px;"> Assignment Code: _____  </div> <div style="border: 1px solid black; padding: 5px; margin-bottom: 5px;"> Date Lesson Received: _____  </div> <div style="border: 1px solid black; padding: 5px;"> Lesson Recorded _____  </div>	

Lesson Number

Module Number (if applicable)

Course Name and Number

Student File Number

Bar Code (same information as above)

Student's Questions and Comments

LESSON

FILE NUMBER  
MODULE  
COURSE NAME  
Name  
Address

Please verify that preprinted label is for correct course and lesson.

Student name and Address

Teacher's Comments:

Correspondence Teacher \_\_\_\_\_

St. Serv. 14-91

**When revised labels are received, place the correct new labels on your Lesson Record Forms.**

**DO NOT MARK OR COVER BAR CODING.**

**CHANGE OF ADDRESS**

If the address on your lesson record form differs from the address you supplied on your registration application, please explain. Indicate whether the different address is your home, school, temporary or permanent change of address.



# LESSON RECORD FORM

1746 Mechanics 12  
Module 1

## FOR STUDENT USE ONLY

Date Lesson Submitted

(If label is missing  
or incorrect)

File Number

Time Spent on Lesson

Lesson Number

## Student's Questions and Comments

Apply Lesson Label Here

Name

Address

Postal Code

Please verify that preprinted label is for  
correct course and lesson.

## FOR SCHOOL USE ONLY

Assigned

Teacher: \_\_\_\_\_

Lesson Grading: \_\_\_\_\_

Additional Grading

E/R/P Code: \_\_\_\_\_

Mark: \_\_\_\_\_

Graded by: \_\_\_\_\_

Assignment Code: \_\_\_\_\_

Date Lesson Received:

Lesson Recorded \_\_\_\_\_

Teacher's Comments:

Correspondence Teacher

## **ALBERTA DISTANCE LEARNING CENTRE**

### **MAILING INSTRUCTIONS FOR CORRESPONDENCE LESSONS**

#### **1. BEFORE MAILING YOUR LESSONS, PLEASE SEE THAT:**

- (1) All pages are numbered and in order, and no paper clips or staples are used.
- (2) All exercises are completed. If not, explain why.
- (3) Your work has been re-read to ensure accuracy in spelling and lesson details.
- (4) The Lesson Record Form is filled out and the correct lesson label is attached.
- (5) This mailing sheet is placed on the lesson.

#### **2. POSTAGE REGULATIONS**

Do **not** enclose letters with lessons.

Send all letters in a separate envelope.

#### **3. POSTAGE RATES**

First Class

**Take your lesson to the Post Office and have it weighed. Attach sufficient postage and a green first-class sticker to the front of the envelope, and seal the envelope.** Correspondence lessons will travel faster if first-class postage is used.

**Try to mail each lesson as soon as it has been completed.**

**When you register for correspondence courses, you are expected to send lessons for correction regularly. Avoid sending more than two or three lessons in one subject at the same time.**

## ENGINE TYPES

Introduction  
Heat Engines  
Internal Combustion Engines  
External Combustion Engines

### INTRODUCTION

People have always searched for ways to take the drudgery out of everyday living. The problem of how to make work easier occupies much of our time.

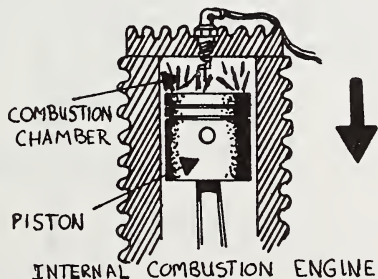
Simple human-powered devices have given way to complex petroleum powered machines. With the development of the modern day engine, we can produce more goods more easily for less money. We can also transport these products to all parts of the world promptly and efficiently.

### HEAT ENGINES

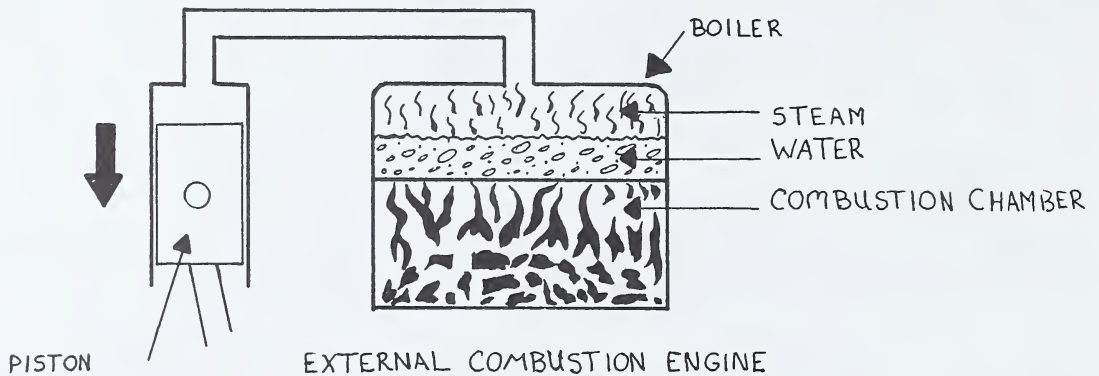
The huge smoke-puffing steam locomotives of a few years ago, the powerful diesel locomotives of today, the streamlined automobile, the noisy lawn mower and the high flying space shuttle all have a common source of power. Each has an engine that is driven by the energy of a burning fuel. This is the reason they are called **heat engines**.

Heat engines are classified into two basic types, **internal combustion** and **external combustion**.

Internal combustion (IC) engines use energy from the burning of fuel inside the engine itself. A good example of the internal combustion type is the familiar piston engine used in most passenger cars.



External combustion (EC) engines use energy from fuel burned outside the engine. An example of the external combustion type is the steam engine.



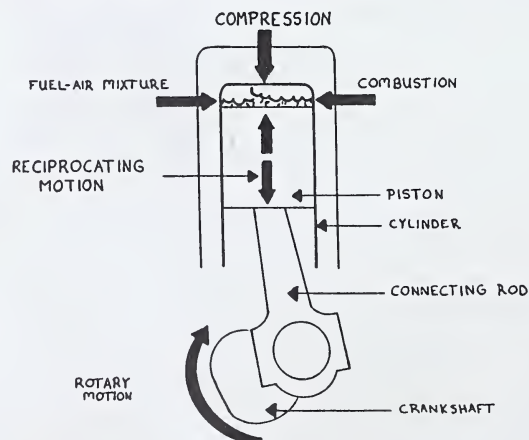
Heat engine types range from conventional piston engines to diesels, rotary engines, gas turbines, Stirling engines, steam engines, free-piston engines, jet engines and rockets.

## THE INTERNAL (I.C.) COMBUSTION ENGINE

### 1. The Reciprocating Piston Engine

A piston engine is defined as being a device in which the energy of a burning fuel forces a piston downward in a cylinder and where the heat energy is converted to useful mechanical energy. In order to achieve this result appropriate amounts of air and fuel must be burned in an enclosed cylinder at a controlled rate. An average air-fuel ratio for good combustion is approximately 15 parts of air to 1 part of fuel, by weight.

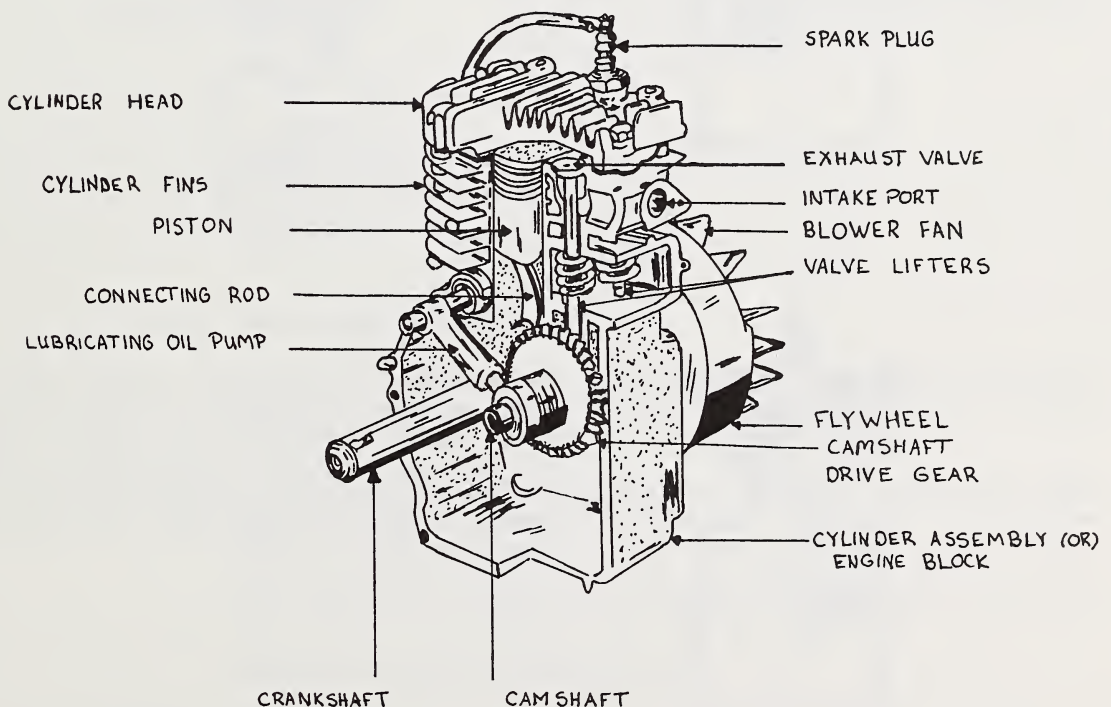
The piston in the cylinder is connected by a pin to the top of a connecting rod. The bottom of the connecting rod is attached to the offset portion of a crank. As the fuel burns it expands, thus forcing the piston downward. This force is transferred via the connecting rod to the crankshaft causing it to rotate. The up and down (**reciprocating**) movement of the piston is converted to circular (**rotary**) motion by the crankshaft. This rotary motion is then usable to drive the vehicle.



The conversion of potential energy in a fuel to mechanical energy by an internal combustion reciprocating engine is only about 33 percent efficient. Of this amount about one third of the heat energy available in the fuel is lost through the exhaust system and another third is lost through the cooling system. One half of the remaining third is lost through friction in the engine and the drive train. This leaves about 15 percent of the available energy in the fuel to drive the vehicle's wheels.

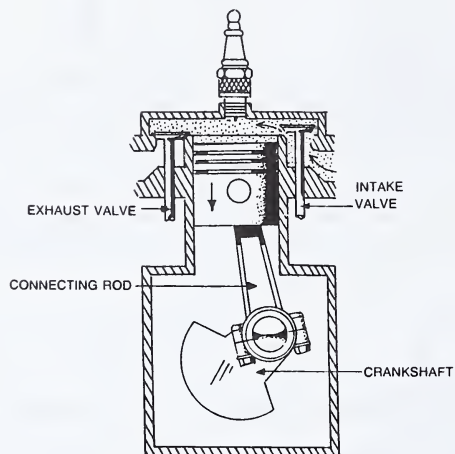
## 2. Basic Engine Components

The basic engine of the one-cylinder variety consists of a cylinder (usually referred to as the engine block) and a piston inside the cylinder which is attached to the crankshaft by the connecting rod. There are two valves (intake and exhaust) which are operated by a second shaft called the camshaft. One end of the crankshaft is attached to the flywheel and the other end of the crankshaft has a gear attached to it which is used to drive the camshaft gear. The camshaft gear is twice as large as the crankshaft gear. This causes the camshaft to turn at half the speed of the crankshaft. Study the drawing below.

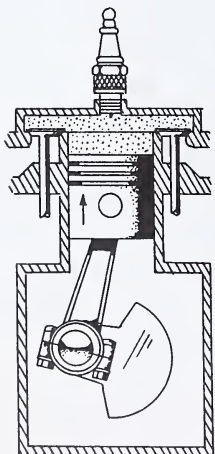


### 3. The Four-Stroke-Cycle Engine

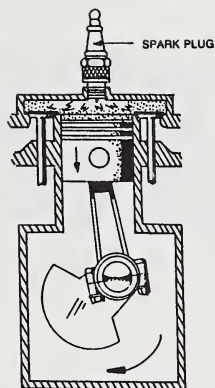
The movement of the piston from its upper limit (TDC or top dead center) to its lower limit, (BDC or bottom dead center) is called a stroke. Engines which operate on the four-stroke-cycle principle complete a series of events (one cycle) involving four strokes of the piston. These events are: the intake stroke, the compression stroke, the power stroke, and the exhaust stroke. A complete cycle involves two revolutions of the crankshaft and one revolution of the camshaft.



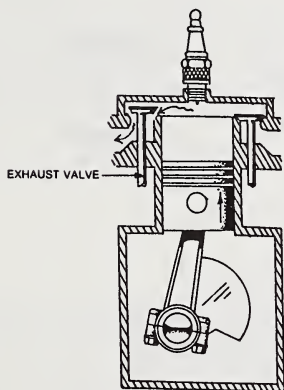
**Intake** — On the intake stroke, the piston moves downward from TDC. This creates a low pressure area (vacuum) in the cylinder. During this time the intake valve is opened by the camshaft motion. Atmospheric pressure forces a mixture of air and fuel past the intake valve into the cylinder in order to fill the low pressure area.



**Compression** — The spinning flywheel keeps the crankshaft turning. The piston is now moving up from BDC and the intake valve closes. The air-fuel mixture is trapped in the cylinder above the piston. The piston continues to travel upward until reaching TDC, compressing the air-fuel mixture to about one-eighth its original volume. The compression stroke is complete.



**Power** — When the piston is at or near TDC, the air-fuel mixture is ignited by a spark from the spark plug. As burning (combustion) takes place, the expansion of the gases causes a rapid rise in pressure inside the cylinder. This pressure forces the piston down, causing the crankshaft to rotate. The power stroke is complete when the piston has reached BDC.



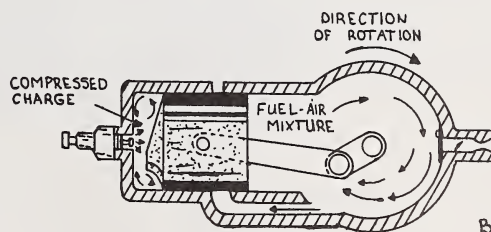
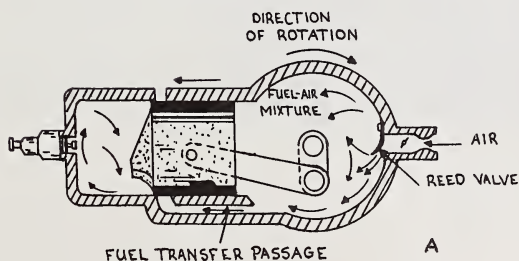
**Exhaust** — When the piston reaches BDC, the exhaust valve opens, and the exhaust gases are pushed out by the piston on its upward stroke. Once the exhaust gases are pushed out and the piston is at the top of the cylinder, the cycle is complete.

#### 4. The Two-Stroke-Cycle Engine

The two-stroke-cycle engine, commonly called the two cycle engine requires only two strokes of the piston and one revolution of the crankshaft to complete one cycle of four events: intake, compression, power, and exhaust.

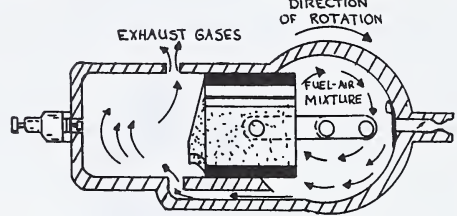
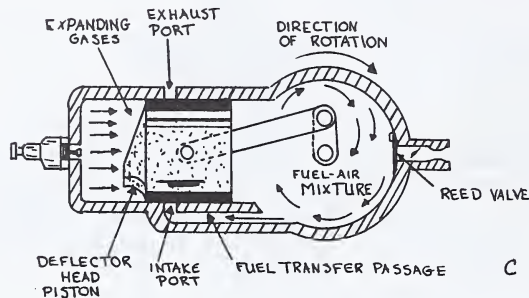
You may have noticed that many lawnmowers, chain saws, motorbikes, snowmobiles use a 2 cycle engine. The engine looks much like a 4 cycle engine, except that it has fewer moving parts. A single cylinder two cycle engine in fact, has only 3 moving parts; a piston, a connecting rod, and a crankshaft. There are no poppet valves, cams, valve lifters, rocker arms, or timing chains. The engine is relatively simple. The two cycle engine fires each time the piston reaches TDC.

##### Stroke One - Intake and Compression



In diagram A the piston moves from BDC towards TDC. As the piston travels from BDC, the air-fuel mixture which has filled the cylinder is being compressed between the top of the piston and the end of the cylinder. At the same time, this motion of the piston decreases the pressure in the crankcase to less than atmospheric pressure. This causes the reed valve to open allowing a fresh air-fuel mixture to enter the crankcase area. When the piston nears TDC (see diagram B) the ignition system fires the spark plug so that it will ignite the air-fuel mixture by the time the piston actually reaches TDC.

### Stroke Two – Power and Exhaust



The expanding gases caused by the burning of the air-fuel mixture force the piston toward the crankshaft and BDC (see diagram C). The reciprocating motion of the piston is converted to rotary motion by means of a connecting rod. The piston motion also compresses the air-fuel mixture in the crankcase. This causes the reed valve to close trapping the air-fuel mixture in the crankcase and preventing blowback into the carburetor.

As the piston continues to move toward BDC, it first uncovers the exhaust port of the cylinder, and then the intake port. As the exhaust port is uncovered, the remaining pressure of the expanding gases is released through the port, carrying with it the by-products of combustion.

When the intake port is uncovered the pressure in the cylinder is less than the pressure in the crankcase. This allows the slightly compressed fuel mixture in the crankcase to enter the cylinder (see diagram D). The special design of the piston and cylinder direct the mixture to all parts of the cylinder simultaneously pushing the remaining exhaust gases through the exhaust port.

When the piston reaches BDC the cycle is complete. The momentum of the flywheel continues to rotate the crankshaft and the cycle begins again.

Since the crankcase of a two cycle engine is used for the fuel-air mixture instead of as a sump for engine oil, the oil to lubricate the internal parts of the engine must be mixed with gasoline in ratios specified by the manufacturer. Another system of lubrication uses an oil pump to inject oil in measured amounts into the fuel-air mixture. This injection is usually done close to the carburetor. Excess oil in the mixture is burned with the air-fuel mixture.

A drawback of the 2 cycle design is that the hot exhaust port is on one side of the cylinder, and the relatively cool transfer ports are on the other side. This uneven heating can distort the bore of the cylinder. Also the 2 cycle engine runs much hotter overall than a 4 cycle engine, because there is no intermediate stroke where fresh fuel mixture comes in and cools the piston and cylinder. Since the 2 cycle engine also fires twice as often as the 4 cycle type, you can expect that more heat will be produced. This increased heat leads to accelerated piston and cylinder wear. The two stroke engine also wastes fuel. By the way it is designed some fresh fuel-air mixture will inevitably find its way out the exhaust pipe before it has even been compressed and burned.

Despite these drawbacks, the 2 cycle engine has many attractive features. It is a very simple engine and this makes it inexpensive to manufacture. The simplicity also makes it easy to maintain, there being no valves to adjust or regrind. Since the 2 cycle fires twice as often as the 4 cycle, the power flow is smoother and more continuous. With very small engines, the fuel wastage of a 2 cycle engine is almost negligible. Since the crankcase does not contain a sump of oil for lubrication, the engine can operate in any position. Thus, applications requiring small, relatively maintenance free, and inexpensive engines, the two-stroke-cycle engine fulfills the requirements quite well.

## 5. The Diesel Engine

The diesel engine is mechanically similar to a gasoline engine. Both types of engines use air, fuel, compression, and ignition of the fuel to produce power. The cycle of events; intake, compression, power, and exhaust occur in the same sequence. Similar arrangements of pistons, connecting rods, and crankshafts occur in both types of engines.

In gasoline engines, fuel and air are mixed together in proper proportions outside the cylinder in the carburetor before they enter the cylinder of the engine. However, in a diesel engine only air enters the cylinders. The air is very highly compressed by the compression stroke of the piston, and diesel fuel is injected into the cylinder just before the piston reaches TDC.

During compression, the air inside the cylinder becomes extremely hot. This causes the diesel fuel to ignite and burn as it is injected into the hot air. Spark plugs and other electrical ignition components are not required in diesel engines as the fuel is ignited through compression. For this reason, diesel engines are sometimes referred to as compression ignition (CI) engines. However, in some diesel engines, glow plugs are used to assist in cold weather starting.

The speed of the diesel engine is controlled by the amount of fuel injected and not by the amount of air that is allowed to be pulled through the carburetor as in the gasoline engine. The temperature inside the combustion chamber goes very high, around  $2500^{\circ}\text{C}$  and the pressure reaches 10 350 kPa. This is 2.5 times the pressure inside a gasoline engine, thus developing tremendous power. The high compression ratio is what gives this engine so much power and efficiency. To withstand these high pressures, a diesel engine must be made much more stronger and heavier than a gasoline engine. The pistons, connecting rods, and crankshaft must be made especially strong. The extra mass is not a drawback on heavy trucks and machinery.

The fuel is injected only at the last moment and it has a very short time to entirely mix with the compressed air. However, it is important that combustion is completed early in the firing stroke. This is accomplished in two ways.

First, the injector nozzles are designed in such a way that they spray the fuel into tiny fine droplets. Secondly, the combustion chamber is designed in such a way that the air in the cylinder will be in violent motion when the fuel is sprayed in. This will produce adequate mixing of the fuel and hot air to ensure complete combustion.

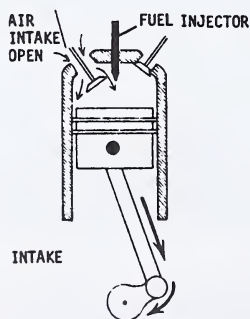
The diesel engine is one of the most efficient of all internal combustion engines. It converts up to 40% of the energy in the fuel to mechanical power, and does this while using a cheaper grade of fuel. The diesel engine is used wherever a heavy job must be done in the cheapest most efficient manner. Hence they are used in large trucks, railway locomotives, buses, and heavy duty equipment such as road graders. Many automobiles are now available with a diesel engine.

Advantages of the diesel engine include less maintenance required, longer engine life, less harmful pollutants, better energy conversion, and lower fuel consumption.

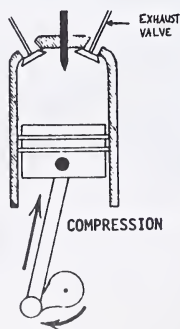
Disadvantages of the diesel engine include higher initial cost when purchasing, some objectional fuel odor, harder starting in cold weather, higher repair costs, less rapid acceleration, greater weight, and noisier operation.

Diesel engines are available in both two and four-stroke-cycle. The four-stroke-cycle diesel engine is commonly used in automobile vehicles. Their design is similar to the four-stroke-cycle gasoline engine. The two-stroke-cycle diesel engine is used primarily in heavy equipment, heavier vehicles and many industrial applications.

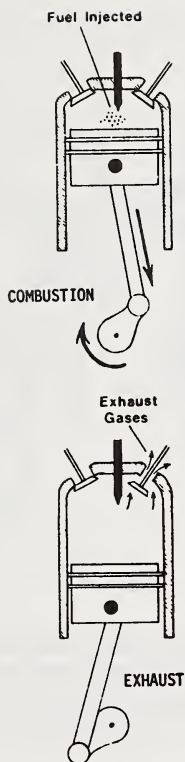
### Four-Stroke-Cycle Diesel Operation



**Intake** — During the intake stroke the piston is moving downward toward BDC. The intake valve opens and air only is drawn into the cylinder from the manifold.



**Compression** — Both valves are closed and the piston moves upward towards TDC. The temperature of the air rises greatly as it is being compressed.

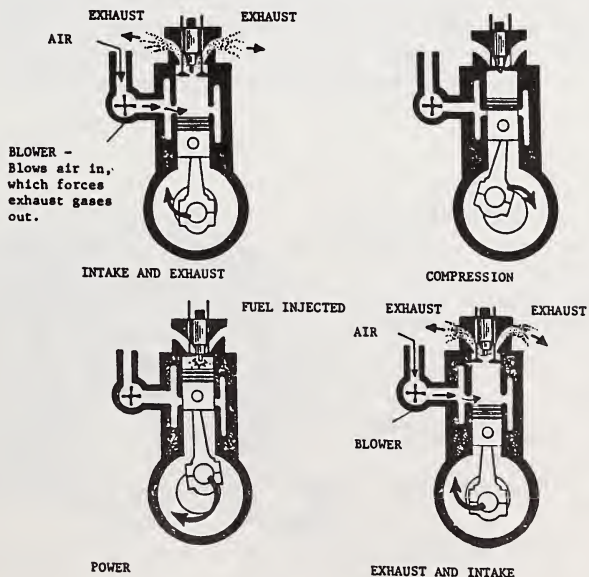


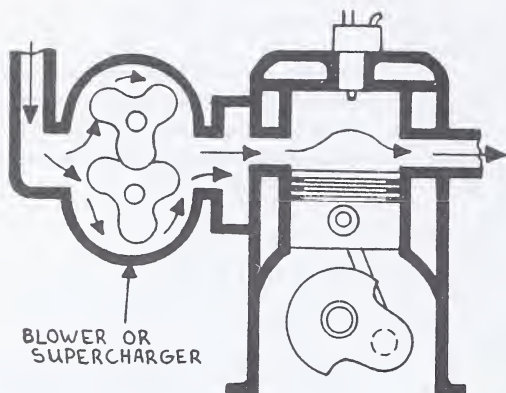
**Power** — Just before the piston reaches TDC, diesel fuel is injected into the cylinder under very high pressure. The fuel vaporizes and ignites immediately in the heated air forcing the piston downward.

**Exhaust** — When the piston reaches BDC the exhaust valve opens and the momentum of the flywheel moves the piston upward pushing the exhaust gases through the open valve. When the piston reaches TDC, the cycle is ready to begin again.

### Two-Stroke-Cycle Diesel Operation

There are also diesel engines that work on a two-stroke-cycle. The basic differences between a two-stroke gasoline engine and a two-stroke diesel engine are: the two-stroke diesel engine usually utilizes an exhaust valve, no fuel mixture enters the crankcase, and a supercharger or blower is used to blow air into the cylinder which forces the exhaust gases out.





SOME 2 CYCLE DIESELS DO NOT USE ANY VALVES AT ALL.

THE EXHAUST GASES ARE BLOWN OUT BY THE INCOMING FRESH AIR.

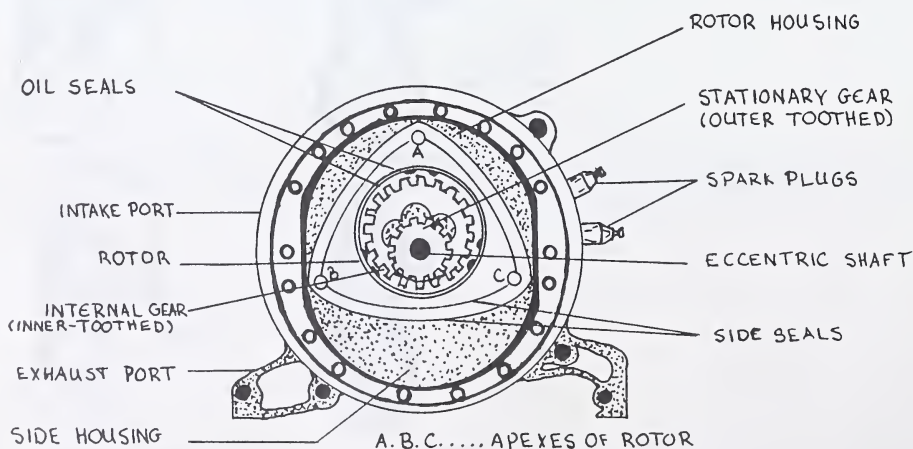
## 6. Rotary Engine

The piston engines that we have looked at so far are reciprocating engines. This means that the driving unit (piston) moves back and forth inside the cylinder. In one revolution the piston changes direction twice. This change of direction makes vibration a problem.

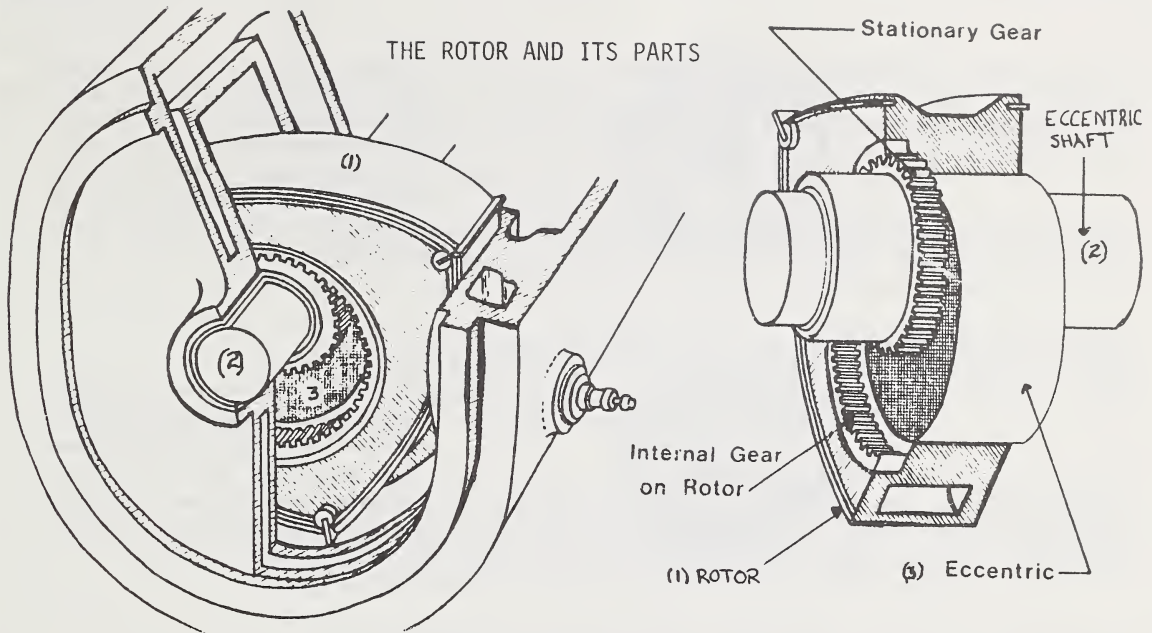
In the rotary combustion engine, also known as the rotary engine or Wankel engine, the motion is entirely rotary (circular). In addition, there are fewer moving parts compared to the large number of moving parts in the four-cycle piston engine.

The rotary engine is a four-cycle engine and completes the four strokes involved — intake, compression, power, and exhaust — in one cycle.

The main unit of the rotary engine is a three-sided rotor. The rotor moves on an eccentric shaft inside a chamber which is shaped like the outside of a figure eight (epitrochoid). The rotor is controlled by a gear so that it completes a specific rotary motion as it rotates around the eccentric shaft.

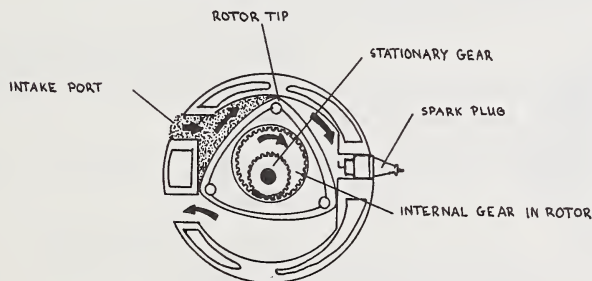


## THE ROTOR AND ITS PARTS

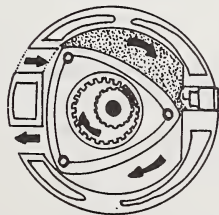


Each side of the rotor acts much as a conventional piston in that it draws in the fuel-air mixture, compresses it, applies the power of the burning mixture to the eccentric shaft and then expels the burned mixture. However, instead of a reciprocating action, the rotor continually revolves in the same direction as the eccentric shaft.

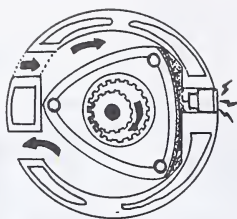
To make things less complicated to follow, study the strokes of the rotary engine concentrating on just one side of the rotor as shown below. The rotor is rotating clockwise in the housing.



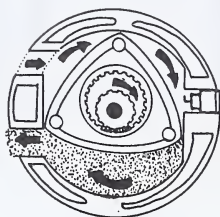
**Intake** — As one rotor tip uncovers the intake port a mixture of fuel and air is drawn into the chamber. This happens due to the increasing volume and thus the decreasing pressure in the chamber.



**Compression** — As the rotor continues to rotate, the second tip of the rotor passes the intake port. This seals the chamber. The decreasing volume of the chamber compresses the fuel mixture.

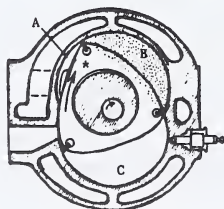


**Power** — Just before the mixture reaches full compression the spark plug(s) fire igniting the fuel mixture. The expanding gases push against and rotor producing the power stroke. Most rotary engines use two spark plugs for ignition due to the flat shape of the combustion chamber.

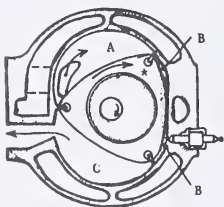


**Exhaust** — As the rotor continues to revolve, the leading tip of the rotor uncovers the exhaust port. The exhaust gases are pushed out as the chamber decreases in size. For each rotation of the rotor, the output shaft (eccentric shaft) makes three revolutions.

In the actual working cycle, more than one event in the cycle (3 events) take place as the rotor makes one revolution. One event occurs on each side of the rotor. Refer to the following diagrams for examples:



- A. Here a corner of the rotor has just passed the intake port, and has just uncovered it.
- B. Fuel-air mixture being compressed.
- C. Burning, expanding fuel.



- A. As the rotor turns, the space between it and the chamber wall increases and a mixture of gasoline and air is pushed in to fill the vacuum.
- B. Ignition just taking place.
- C. Spent mixture being exhausted.

The rotor is the heart of the rotary engine, as this is the part that receives the power of the burning gases. The rotor has a depression in each of the three faces. This depression acts as the combustion chamber. The size of the depression also controls the compression ratio. If the depression is larger, the engine has less compression, if smaller, then it has higher compression.

The rotor has an internal ring gear located in its hub and this runs around a stationary gear that is fixed to the end housing. This arrangement makes sure that the rotor rotates in the correct sequence.

The rotor also rides on an eccentric shaft. This shaft essentially serves the same function as a crankshaft does in a piston engine. Because of the gearing of the rotor, the eccentric shaft turns at three times the speed of the rotor, so if the engine is turning at 3 000 rev/min, the rotor is turning at only 1 000 rev/min..

A problem when the engine was first being developed, was how to get the rotor to seal well. This has largely been solved by using special apex seals and side seals. These seals are kept pressing against the sides of the housing by small springs under the seals. The problem of sealing and wear seems to have been solved to the point where one manufacturer offers a very extensive warranty with the engine.

The rotor housing is usually made of aluminum or cast iron. If it is made of aluminum, a thin layer of chrome is deposited on the surface to make it resistant to wear. There is an outer jacket surrounding the housing and within it flows the coolant to take away excess heat.

The rotary engine uses a pressure lubrication system, with oil routed to all critical surfaces in the engine. The oil is also used for cooling the rotors by being pumped through hollow cavities in the rotor and so carrying off excess heat. The hot oil is then cooled by being put through an oil cooler. To lubricate the apex seals a metering oil pump feeds a small amount of oil to the carburetor where the oil is mixed with the gasoline-air mixture.

The rotary engine puts out more power than a comparable size piston engine. This can be illustrated by the following example. A certain piston engine has a displacement of 1 587 cm<sup>3</sup> and develops 47.744 kW. The rotary engine on the other hand is a bit smaller having a displacement of 1 312 cm<sup>3</sup> but develops 82.060 kW. This particular engine uses two rotors.

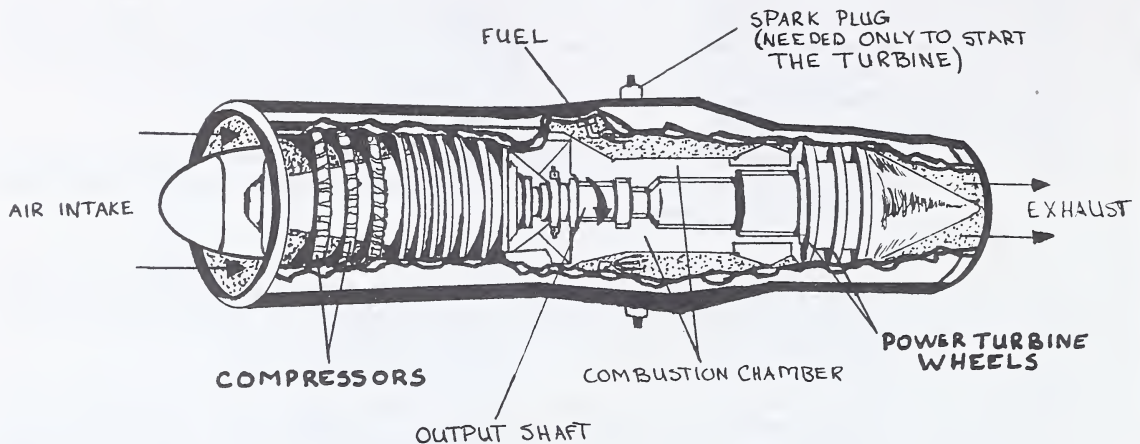
The rotary engine is also smaller, being about half the size of a typical six cylinder engine of the same power. This makes the engine relatively light. As there are no reciprocating parts, the rotary engine is much smoother in operation than a piston engine.

## 7. The Gas Turbine Engine

The gas turbine is an internal combustion engine. This means that it has a combustion chamber in which fuel is burned.

Gas turbines have three major parts:

1. compressors
2. combustion chamber
3. power turbines



The air is drawn into the compressor through the air intake. It is compressed many times that of atmospheric pressure which causes the temperature to rise. The heated air is forced from the compressor into the combustion chamber where it is mixed with fuel. The spark plug fires and ignites the air-fuel mixture. The expanding gases apply force against the blades of the power turbine wheels causing them to rotate. The turbine wheels provide power to the output shaft to drive the wheels of the vehicle.

The gas turbine is essentially a very simple machine and needs very few accessories. There is no need for a radiator, and the electrical system is quite simple. There is only a single spark plug, and it is only used for starting the turbine. Once the turbine has started, it continues operating without the need of a spark plug. It is interesting to note that the gas turbine has the same cycles as the four-stroke-cycle piston engine — intake, compression, power, and exhaust. The difference is that, in a gas turbine, the cycles are taking place at the same time. Thus, the combustion process is continuous rather than intermittent as in a piston engine. This continuous flow of power, the complete lack of any reciprocating parts, and the perfect balance of the rotors, makes the gas turbine a very smooth powerplant.

There is also a notable lack of rubbing parts in the gas turbine. This simplifies the lubrication requirements, as well as cutting down on the number of parts that have to be replaced as a result of wear. The only rubbing parts in the gas turbine are the shafts the turbine wheels run on and the few shafts and gears that are used to drive accessories.

Another very important advantage of the gas turbine is that they are small and light for the amount of power they can produce. For example, a turbine engine weighing 160 kg can produce as much power as a 6 350 kg piston engine.

The gas turbine is also a versatile power plant. It can run on a wide variety of fuels such as gasoline, kerosene, diesel oil, or jet fuel. Almost anything that is liquid and will burn can be used. Since the turbine can operate on various fuels, it can be used in many parts of the world. If, for example, you had an engine that could only use a special high grade of gasoline, then you could not use that engine in a country where that high grade gasoline is not available. Since the gas turbine does not need any special fuel, it can be used in many countries and areas where only diesel oil was available. The turbine is also able to start very well at low temperatures, making it ideal for Arctic and Antarctic climates.

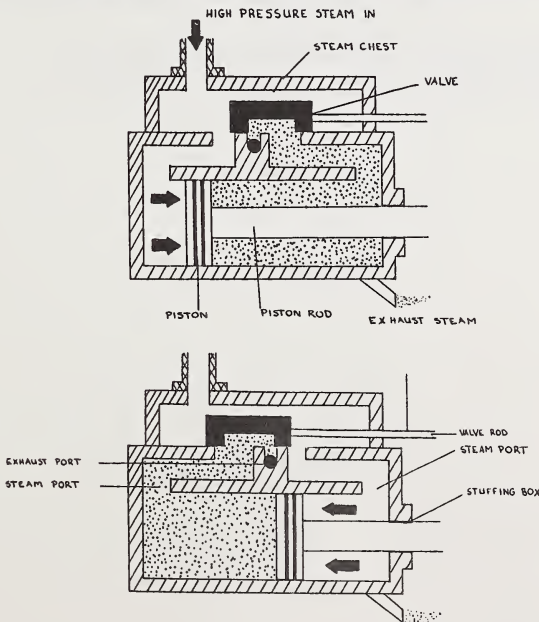
Some present day uses of the gas turbine are in locomotives, stationary power plants, trucks and buses, ships, and some limited use in experimental passenger cars. The turbine used in the experimental cars have about the same efficiency as the diesel engine. Their use is limited to experimental cars due to the high manufacturing costs of the engine. However, with the ever increasing price of gasoline, the initial engine cost becomes less of a determining factor.

One of the disadvantages of the gas turbine is the difficulty of developing materials for the turbine blades. They must be able to withstand both high temperatures and high centrifugal forces resulting from high rotation speeds. Another disadvantage is that gas turbines have low torque at low speeds. This limits their usefulness in automobiles, for example.

## THE EXTERNAL COMBUSTION ENGINE

### 1. The Reciprocating Steam Engine

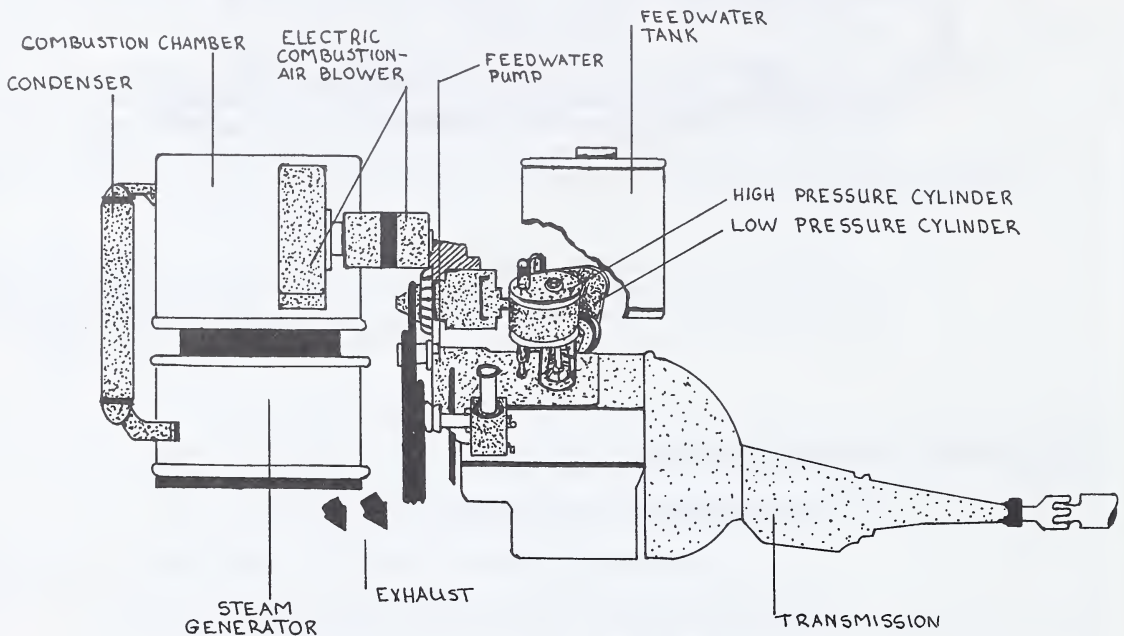
In a simple steam engine the fuel is burned in a firebox and heats a boiler. The heat converts water into high pressure steam which is transported to the engine cylinder where it is converted to usable mechanical energy to drive a vehicle.

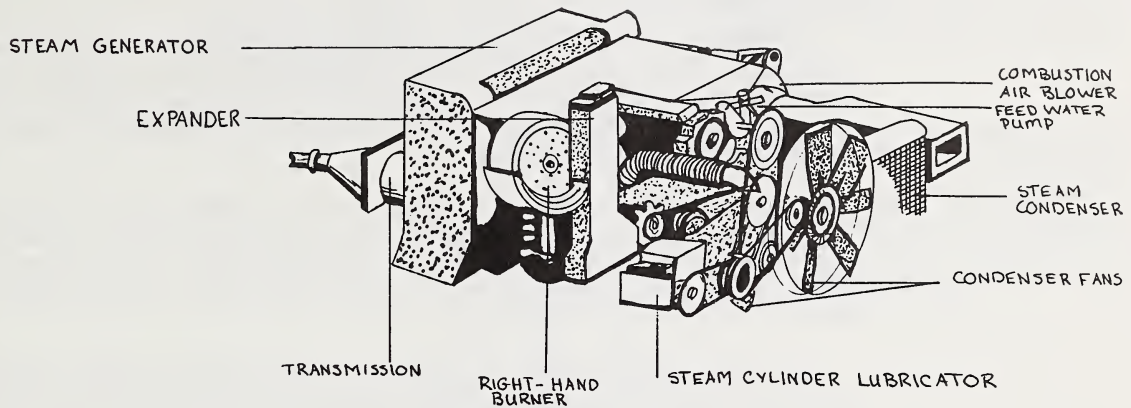


**Stroke One** — The high pressure steam enters the cylinder through the slide valve. This forces the piston back in the cylinder. The decreasing space behind the piston forces the exhaust steam out through the exhaust port. The motion of the piston is transferred via the piston rod to the crankshaft causing it to turn.

**Stroke Two** — When the piston reaches the end of the first stroke, the slide valve moves allowing steam to enter the cylinder on the opposite side of the piston. The steam pressure forces the piston back up the cylinder and again pushes the exhaust steam out through the exhaust port. When the piston reaches the end of this stroke the cycle repeats itself.

The automotive industry is presently experimenting with steam powered vehicles. A number of steam vehicles have been developed and are being evaluated in terms of reliability, performance, passenger comfort, and economy. The steam engine is receiving increased interest because it is environmentally clean. The following diagrams show a steam powered automobile designed by General Motors Corporation.





General Motors Corp. SE101 Steam Car

Weight and size of the power plant are the steam engined vehicle's major disadvantages. Even though the engine is much larger than the internal combustion engine it replaces, it only puts out half the power.

Since water is still the best working fluid for steam power, it must be protected against freezing temperatures. The addition of antifreeze reduces the effectiveness of water as a working fluid and also creates serious pollution problems.

Lubrication tends to be difficult as lubricants must be mixed with steam at high temperatures and pressures. These lubricants must be removed before the steam is condensed to water otherwise it damages the boiler.

Even though the steam engine is not yet a practical power source for automotive use it still remains a contender for a low emission power plant for the future.

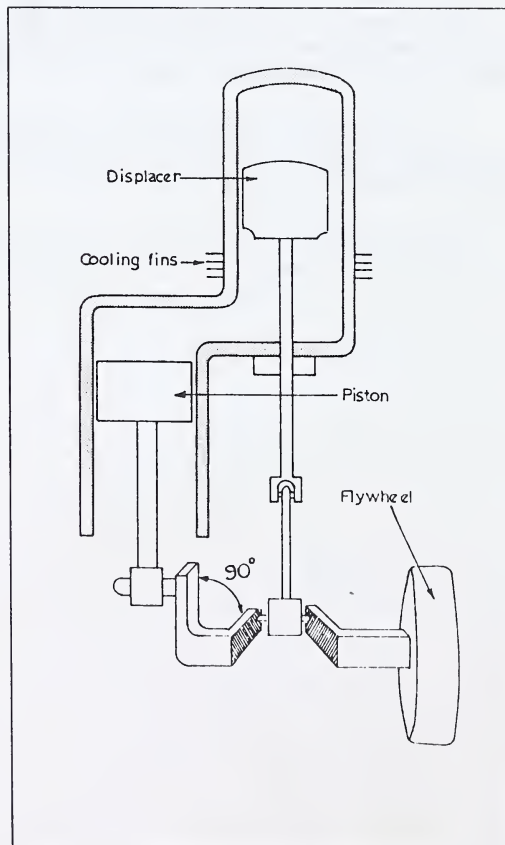
## 2. The Stirling Engine

Another engine being experimented with is the Stirling engine. In this engine combustion takes place outside the cylinders, and combustion is more complete. This engine could cut down significantly on air pollution, if it was used in place of the conventional gasoline engine. It is for this reason firms like Philips Research Laboratories are experimenting with these engines.

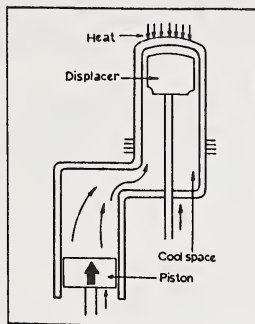
Amazing as it may seem, the Stirling hot-air engine has been around for longer than any except the steam engine. The idea first occurred to Robert Stirling, a Scottish minister, in 1816. He built a successful engine of this kind in 1827. For a long period of time it was forgotten perhaps because of the success of the internal combustion engine. Only recently has it been revived.

The Stirling engine is really very simple. It is made up of two cylinders. Inside one cylinder is a loose-fitting piston called a displacer. One end of this cylinder is kept cool and the other hot. In the second cylinder is a tight-fitting piston which moves back and forth. The two cylinders are connected by a tube which transfers air between them. At one end of the displacer cylinder, heat is applied, usually from outside the cylinder.

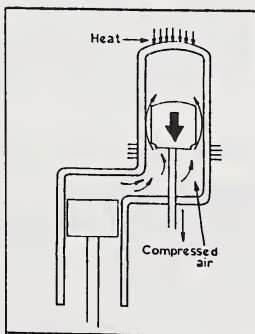
Both the piston and the displacer are connected by means of rods to a crankshaft. The two cranks are positioned  $90^\circ$  apart.



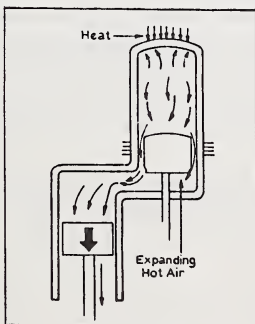
Let us follow one complete cycle of the engine so that we can gain some understanding of the basic principles of its operation. The following diagrams show only the pistons and cylinders, omitting the cranks for purposes of simplicity. Remember that the displacer and the piston are always  $90^\circ$  apart.



Beginning of Compression Stroke



Full Compression - Air Displaced to Hot End

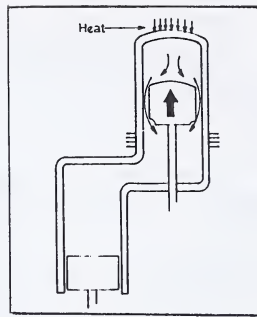


Hot Air Expands, Power Stroke

**Beginning of Compression Stroke** — This piston is beginning to move upward, compressing the air into the cool air space at the bottom of the displacer cylinder. The displacer is near the top of its stroke allowing for maximum cool space.

**Full Compression** — The piston is at the top of its stroke and the air is fully compressed. The displacer is moving down, transferring the cool compressed air to the hot end of the cylinder where heat is applied to it.

**Power Stroke** — The hot air expands and rushes past the displacer to push down on the piston. The displacer is at the bottom of its stroke. As the air expands it cools.

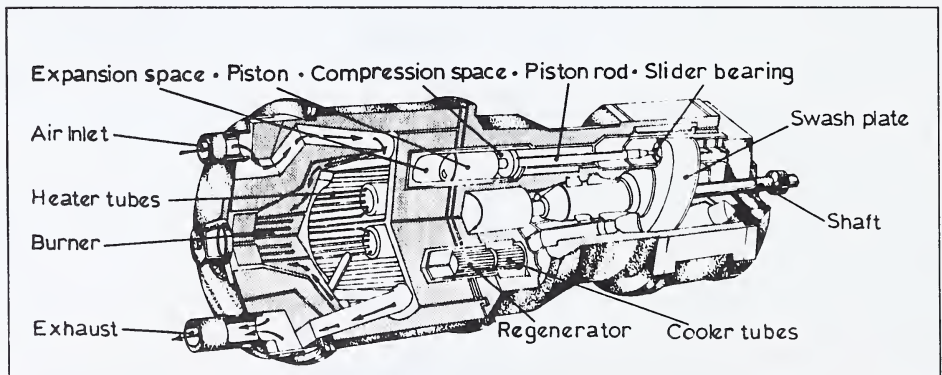


End of Power Stroke

**End of Power Stroke** — The piston is at the bottom of its stroke and the displacer is moving up. The expanded hot air at the top of the cylinder is being displaced and cooled forming a large cool space. The engine now is starting the compression stroke and the cycle repeats itself.

One of the disadvantages of the Stirling engine construction as shown is that quite a bit of the heat is lost through cooling fins. This problem has been solved by the use of a regenerator which stores heat when air goes through it one way and releases it when the air goes in the opposite direction.

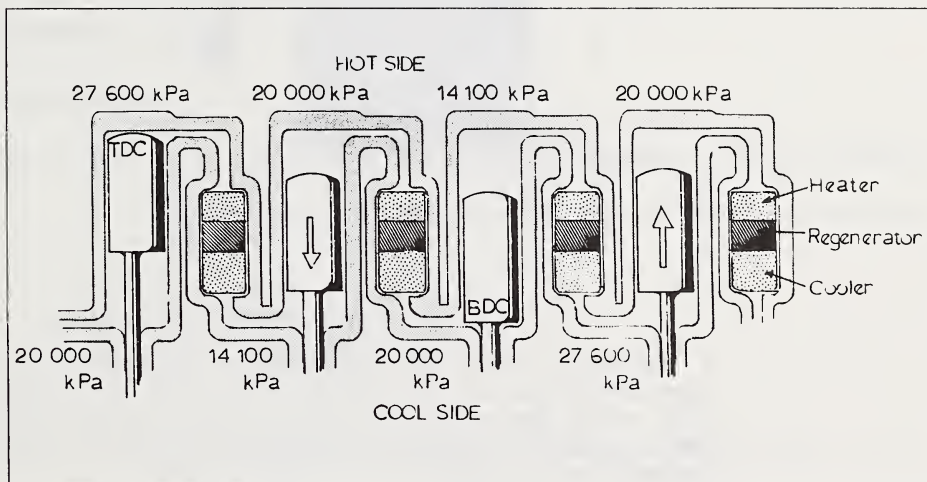
An even better mechanical arrangement utilizes a swash plate. (If you study the diagram below, you will see that a swash plate is a thick disc set at an angle on a shaft.)



Stirling Engine with Swash Plate

The piston rods push alternately on the swash plate, causing it to revolve. Because of the swash plate arrangement, the pistons are interconnected so they have alternating movements. The top space of one cylinder is connected to the bottom space of another cylinder. As the pistons alternate up and down, working gas moves back and forth from cylinder to cylinder. So essentially the pistons alternate in function as being power pistons and displacer pistons. A piston acts as a displacer piston for another piston at one moment, and then can also be a power piston at another point in the cycle. The engine gives one power impulse for every quarter turn of the swash plate or 4 power strokes per revolution.

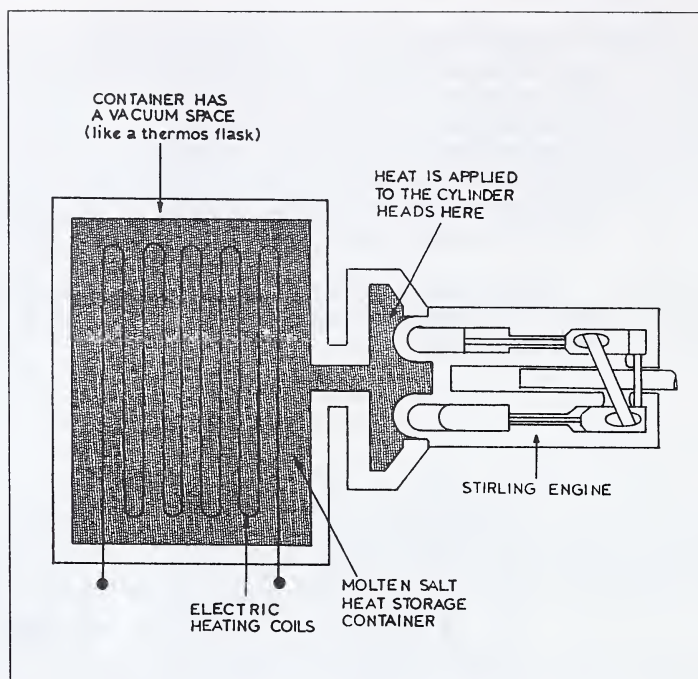
The hot end of one cylinder is connected to cooler end of another cylinder through a regenerator. This regenerator collects heat from hot gases on their way down, and heats cool gases on their way up.



1st Quarter Turn

The Stirling engine has a number of advantages. Exhaust emission levels are very low since the fuel can be burned completely. Fuel economy is 38% better than a comparable internal combustion engine. It can run on anything that can burn, so low grade fuel oil could be used. It has high efficiency at partial load, and good torque over a wider range of speeds than an I.C. engine. The fuel is burned outside the cylinders so oil contamination is almost non-existent and the engine requires very infrequent oil changes. It has an extremely long service life. Test engines at Philips have gone 10 000 h (that's about 500 000 km of driving) non-stop, under full load without any maintenance or adjustment. The engine is also very quiet, since there is no intermittent combustion of gases at high pressures inside the cylinder. The exhaust is released at or near atmospheric pressure.

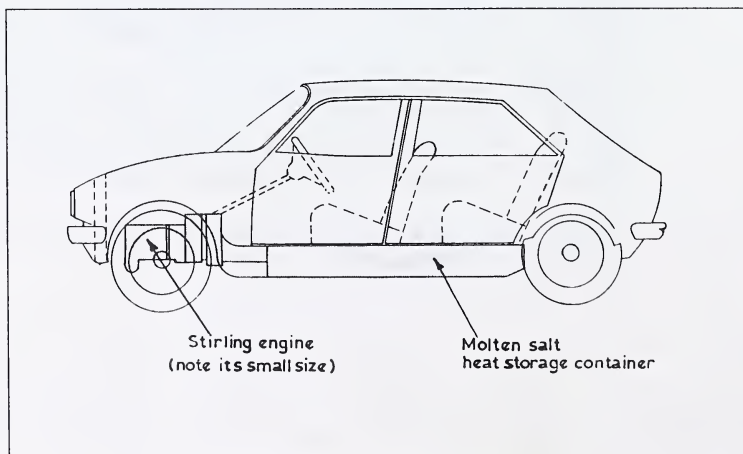
Since the Stirling engine can run on any heat source, it could also run on electricity. The following diagram shows how this can work.



Using Electricity to Power a Stirling Engine

The electric heating coils heat up and actually melt (at  $150^{\circ}\text{C}$ ) a mixture of lithium and magnesium fluoride salts. These salts are in a container that has hollow vacuum insulated walls, much the same as in a thermos flask. The salts are amazingly efficient at storing energy. They can store about 10 times as much energy per kilogram as electric storage batteries. The insulation in the storage unit can keep the salt hot for up to three weeks.

The heat of the salt is applied to the cylinder heads of the Stirling engine and makes it run. When the salt's heat is all used up, you just plug it in overnight and heat it up again. The drawing below shows how the salt heat storage unit would fit in the floor of a small car. At city speeds, the car would have a range of about 300 km. Needless to say it would be completely pollution free.



A Salt Heat Storage Unit

There are some problems that must be resolved before the engine can be put into production. Stirling engines tend to reject more heat through their cooling system than the conventional I.C. engines, therefore proper cooling is a problem.

Hydrogen and helium have proven to be the best working gases for operating the engine. There may be problems containing the gas since the gas would be under tremendous pressure. Also, there could be a safety problem should a leak develop especially if highly flammable hydrogen gas is used.

All these problems present one major drawback; the cost to bring the Stirling engine out of the laboratory and into production for automobiles. However, on a mass production basis the costs could very well be quite competitive with conventional engine costs.

### SELF-CORRECTING EXERCISE 1

Choose the letter of the **best** answer and place it in the blank to the left of the question.

- \_\_\_\_\_ 1. Compared to the crankshaft, the camshaft in a four-stroke-cycle gas engine turns:
- (a) one quarter as fast.
  - (b) one half as fast.
  - (c) the same speed.
  - (d) twice as fast.
- \_\_\_\_\_ 2. On a two-stroke-cycle engine, the downward stroke from TDC to BDC is a combination \_\_\_\_\_ and \_\_\_\_\_ stroke.
- (a) intake; compression
  - (b) intake; exhaust
  - (c) power; intake
  - (d) power; exhaust
- \_\_\_\_\_ 3. What takes the place of the crankshaft and connecting rod in a rotary engine?
- (a) the eccentric
  - (b) the internal gear
  - (c) the rotor
  - (d) the stationary gear
- \_\_\_\_\_ 4. What part of a simple two-cycle gasoline engine temporarily stores the fuel-air mixture until intake?
- (a) the carburetor
  - (b) the crankcase
  - (c) the cylinder
  - (d) the port holes

- \_\_\_\_\_ 5. The compression ratio of a diesel engine compares in what way to that of a gasoline engine?
- (a) It is higher.
  - (b) It is lower.
  - (c) It is about the same.
  - (d) It varies considerably.
- \_\_\_\_\_ 6. The power stroke in a two-cycle gasoline engine occurs
- (a) once every revolution of the crankshaft.
  - (b) once every two revolutions of the crankshaft.
  - (c) twice every revolution of the crankshaft.
  - (d) None of the above
- \_\_\_\_\_ 7. The diesel engine is sometimes referred to as \_\_\_\_\_ engine.
- (a) an external combustion
  - (b) a spark ignition
  - (c) a compression ratio
  - (d) a compression ignition
- \_\_\_\_\_ 8. The diesel engine is more \_\_\_\_\_ in operation than the gasoline engine.
- (a) expensive
  - (b) inefficient
  - (c) efficient
  - (d) costly
- \_\_\_\_\_ 9. What type of engine has very low oil contamination?
- (a) Diesel
  - (b) Stirling
  - (c) Gasoline
  - (d) Rotary
- \_\_\_\_\_ 10. The automotive industry is viewing the external combustion engine with interest primarily because it is \_\_\_\_\_.
- (a) environmentally clean
  - (b) less expensive to manufacture
  - (c) easier on fuel consumption than conventional engines
  - (d) smaller and takes up less room

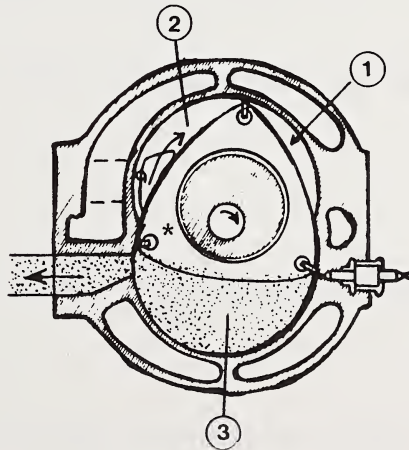
**SELF-CORRECTING EXERCISE 2**

Fill in the blanks with the correct word or phrase.

1. In a piston engine, the reciprocating motion of the piston is converted to rotary motion by the \_\_\_\_\_.
2. In the gasoline engine, fuel and air are mixed in proper proportions \_\_\_\_\_ of the cylinder in a \_\_\_\_\_. However, with a diesel engine only \_\_\_\_\_ is forced into the cylinder. Fuel is \_\_\_\_\_ into the cylinder just before the piston reaches TDC.
3. The speed of a diesel engine is controlled by \_\_\_\_\_ and not be the amount of \_\_\_\_\_ as in the gasoline engine.

**SELF-CORRECTING EXERCISE 3**

Referring to the diagram below:



1. What type of engine is this?

\_\_\_\_\_

2. What is happening in section ①?

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3. What is happening in section ②?

---

4. What is happening in section ③?

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5. Why does this engine run smoother than a comparable piston engine?

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Complete the following exercises and send them in for correction.

**EXERCISE 1**

1. What is the difference between an internal combustion engine and an external combustion engine?

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2. What is the meaning of reciprocating motion?

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3. The reciprocating I.C. engine is about 33 percent efficient. Only about 15 percent of this heat energy available is used to drive the wheels. What happens to the rest?

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4. What feature do the gasoline, the diesel, and the rotary engines have in common?

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5. How does the rotary engine differ from the other two engines?

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6. What advantage does this difference produce for the rotary engine?

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7. Name the strokes of a four-cycle gasoline engine and explain briefly what happens in each stroke.

(a) \_\_\_\_\_

\_\_\_\_\_

(b) \_\_\_\_\_

\_\_\_\_\_

(c) \_\_\_\_\_

\_\_\_\_\_

(d) \_\_\_\_\_

\_\_\_\_\_

## EXERCISE 2

1. What is the main difference between the lubrication system in a 2-cycle and a 4-cycle engine?

\_\_\_\_\_

\_\_\_\_\_

2. Why does the gas turbine start more easily in cold weather as compared to a piston engine?

\_\_\_\_\_

3. How do the diesel engine and gas engine differ as to how ignition of the fuel is achieved?

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

4. Why is a diesel engine more heavily made than the conventional gasoline I.C. engine?

\_\_\_\_\_

5. What are two advantages of a two-cycle gas engine over a four-cycle gas engine?

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6. What are two advantages of the diesel engine over a gasoline engine?

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7. What are two disadvantages of a diesel engine?

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8. What are the two major disadvantages of the automotive steam engine?

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**ANSWERS TO SELF-CORRECTING EXERCISES****Self-Correcting Exercise 1**

- |                        |                 |
|------------------------|-----------------|
| 1. b (page 4)          | 6. a (page 5)   |
| 2. d (page 6)          | 7. d (page 7)   |
| 3. a (pages 10 and 13) | 8. c (page 8)   |
| 4. b (page 6)          | 9. b (page 21)  |
| 5. a (page 7)          | 10. a (page 16) |

**Self-Correcting Exercise 2**

1. crankshaft (page 2)
2. outside; carburetor; air; injected (page 7)
3. the amount of fuel injected; air that is pulled through the carburetor (page 7)

**Self-Correcting Exercise 3**

1. Rotary engine or Wankel engine. (page 10)
2. Compression of fuel-air mixture. (page 11)
3. Intake of fuel-air mixture. (page 11)
4. Exhaust gases are being expelled. (page 12)
5. All components travel in a circular motion as compared with the reciprocating motion in a piston engine. (page 13)

## QUESTIONNAIRE FOR MECHANICS 12

Name: \_\_\_\_\_ File No. \_\_\_\_\_  
Address: \_\_\_\_\_ Male: \_\_\_\_\_  
\_\_\_\_\_ Female: \_\_\_\_\_  
Postal Code: \_\_\_\_\_ Phone: \_\_\_\_\_ Age: \_\_\_\_\_

Please complete the following as this information will help your teacher when writing to you as an individual. This form **must** be returned to the school with Lesson Number One. Thank you.

1. Indicate any courses or experience you may have that are related to Mechanics 12.

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

2. Why are you taking this course? \_\_\_\_\_

Where and how did you find out about this course? \_\_\_\_\_

\_\_\_\_\_

3. Please indicate any experience or qualifications which relate to the course, or any handicaps (jobs, illness, disabilities) which may influence your progress.

\_\_\_\_\_

4. List any other subjects you are taking by correspondence instruction.

\_\_\_\_\_

5. What school are you attending, if any? \_\_\_\_\_

6. If not attending school please give last school attended. \_\_\_\_\_

7. What make and model car do you drive or have access to.

\_\_\_\_\_

8. What tools do you have available to you? \_\_\_\_\_



# LESSON RECORD FORM

1746 Mechanics 12  
Module 1

## FOR STUDENT USE ONLY

Date Lesson Submitted

\_\_\_\_\_

Time Spent on Lesson

\_\_\_\_\_

(If label is missing  
or incorrect)

File Number

\_\_\_\_\_

Lesson Number \_\_\_\_\_

## Student's Questions and Comments

Apply Lesson Label Here

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*Please verify that preprinted label is for  
correct course and lesson.*

## FOR SCHOOL USE ONLY

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Lesson Grading: \_\_\_\_\_

Additional Grading

E/R/P Code: \_\_\_\_\_

Mark: \_\_\_\_\_

Graded by: \_\_\_\_\_

Assignment Code: \_\_\_\_\_

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## **ALBERTA DISTANCE LEARNING CENTRE**

### **MAILING INSTRUCTIONS FOR CORRESPONDENCE LESSONS**

#### **1. BEFORE MAILING YOUR LESSONS, PLEASE SEE THAT:**

- (1) All pages are numbered and in order, and no paper clips or staples are used.
- (2) All exercises are completed. If not, explain why.
- (3) Your work has been re-read to ensure accuracy in spelling and lesson details.
- (4) The Lesson Record Form is filled out and the correct lesson label is attached.
- (5) This mailing sheet is placed on the lesson.

#### **2. POSTAGE REGULATIONS**

Do not enclose letters with lessons.

Send all letters in a separate envelope.

#### **3. POSTAGE RATES**

First Class

Take your lesson to the Post Office and have it weighed. Attach sufficient postage and a green first-class sticker to the front of the envelope, and seal the envelope. Correspondence lessons will travel faster if first-class postage is used.

Try to mail each lesson as soon as it has been completed.

When you register for correspondence courses, you are expected to send lessons for correction regularly. Avoid sending more than two or three lessons in one subject at the same time.

## PISTON ENGINE CLASSIFICATION AND MEASUREMENT

Introduction  
Engine Classification  
Force, Energy, Work and Power  
Engine Measurements and Performance  
Engine Efficiency

### INTRODUCTION

This lesson describes the ways in which engines can be classified according to specific design characteristics. Also included is a discussion of terms such as force, work, energy, power and torque and how they are related to engines.

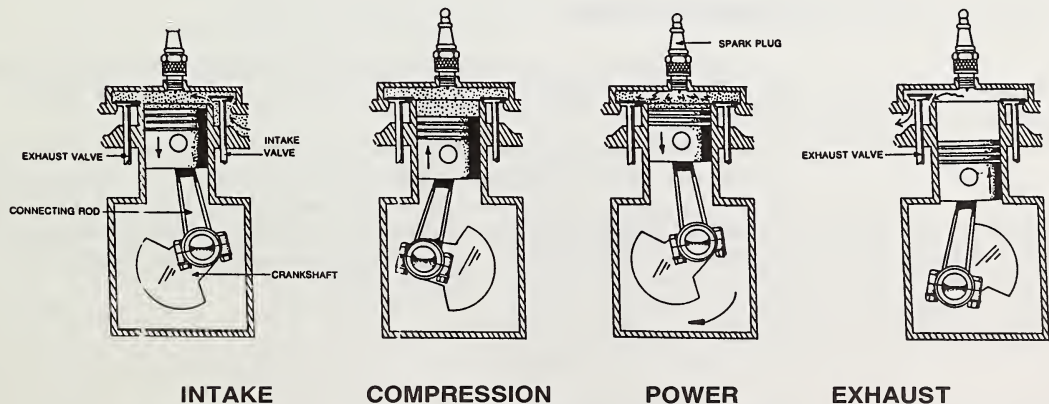
A description of the ways in which engines and engine performance are measured will follow. Terms such as bore, stroke, piston displacement and compression ratio will be discussed.

### ENGINE CLASSIFICATION

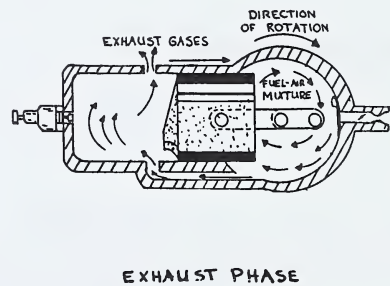
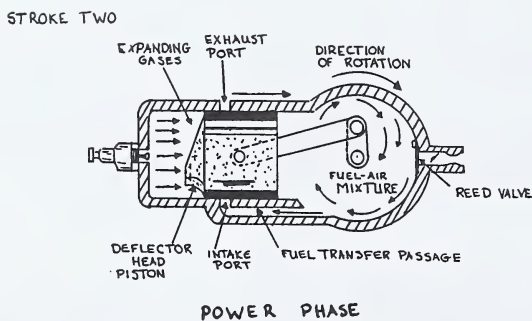
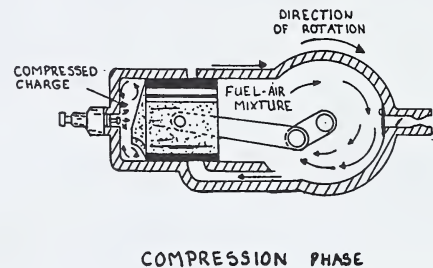
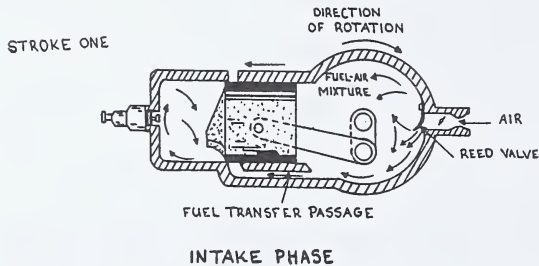
Although engines can be classified in a number of different ways, the classification is dependent on engine design. These design characteristics are:

#### 1. Stroke Cycle

The four-stroke-cycle engine (as discussed in lesson one) requires four strokes of the piston to complete one complete cycle of events: intake stroke, compression stroke, power stroke, and exhaust stroke. In order to complete this cycle of events, two complete revolutions of the crankshaft are required.



The two-stroke-cycle engine requires two strokes of the piston and only one revolution of the crankshaft to complete one cycle of events. Both intake and compression are completed when the piston moves from BDC to TDC and movement from TDC to BDC completes both power and exhaust.



## 2. Cooling Methods

Some engines are cooled by the flow of air around the cylinders and cylinder head of the engine. This type of engine is referred to as an **air-cooled** engine.

**Liquid-cooled** engines dissipate the heat of combustion in yet another way. Heat within the engine is transferred to coolant being circulated in water passages in the engine block. The liquid coolant picks up the heat and delivers it to the radiator where it is cooled and then returned to the engine for recirculation. Liquid-cooled engines are by far the most common type of engine used in the automotive industry.

### 3. Type of Fuel

Gasoline, diesel fuel, and liquified petroleum gas (LPG) fuel systems are currently used with automobile engines.

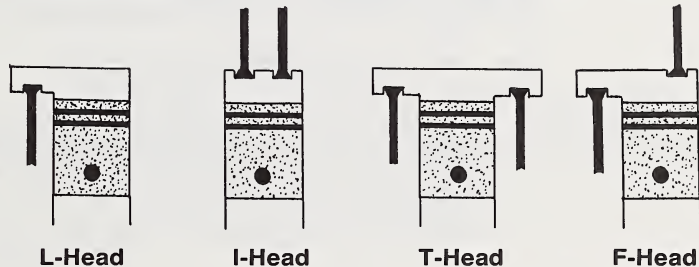
### 4. Ignition Systems

Gasoline and LPG engines use the **spark ignition system**. The spark ignition system causes a spark to occur across the electrodes of a spark plug which ignites the vaporized fuel and air mixture in the cylinder.

Diesel engines are referred to as **compression ignition engines**. These engines use the heat of compressing the air to ignite the fuel when it is injected into the cylinder at the end of the compression stroke.

### 5. Valve Arrangement

Engines can be classified by valve arrangement. Four major types of valve arrangements have been used: L head, I head, T head, and F head. Of these four types, the most common arrangement is the I head, which is also known as the valve-in-head type.



### 6. Cylinder Arrangement

Cylinder arrangement depends upon cylinder block design. Cylinders are commonly arranged in one of three ways:



**In-line design** — Cylinders with in-line design are arranged in a straight line one behind the other. Common in-line designs are the four-cylinder and six-cylinder engines.



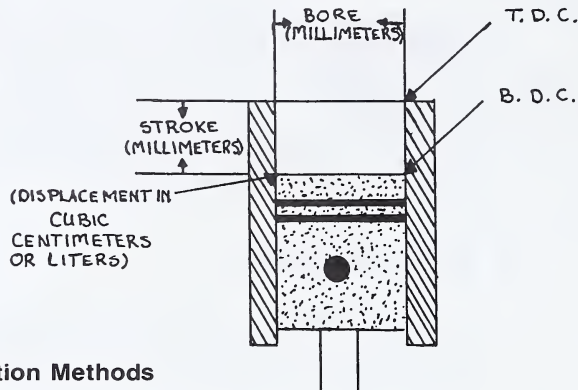
**V-type design** — Engines with the V-type of cylinder design use two banks of cylinders arranged in a 60° or 90° V pattern. The most common V-type designs are the V8, with two banks of four cylinders in a 90° design, and the V6 with two banks of three cylinders in either a 60° or 90° design.



**Opposed-piston design** — This horizontally opposed design uses two banks of cylinders opposite each other. The crankshaft is in between the cylinders and all cylinders are in a horizontal position.

## 7. Engine Displacement

Engine displacement indicates the “size” of the engine in a vehicle. Engine displacement may be defined as the amount of air displaced by the piston when the piston moves from bottom-dead-center (BDC) to top-dead-center (TDC). It varies with cylinder bore size, the number of cylinders, and the length of the piston stroke.

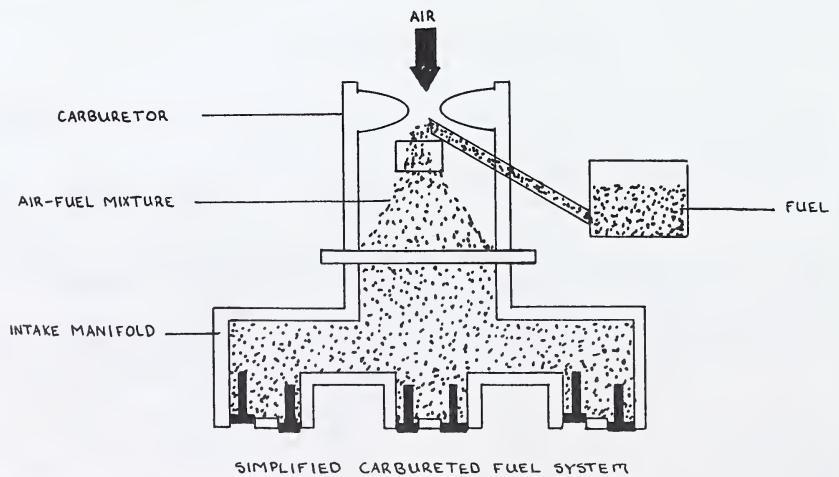


## 8. Fuel Induction Methods

Automobile engines have basically two systems for inducing fuel into their combustion chambers; the **carbureted fuel system** and the **fuel-injection system**.

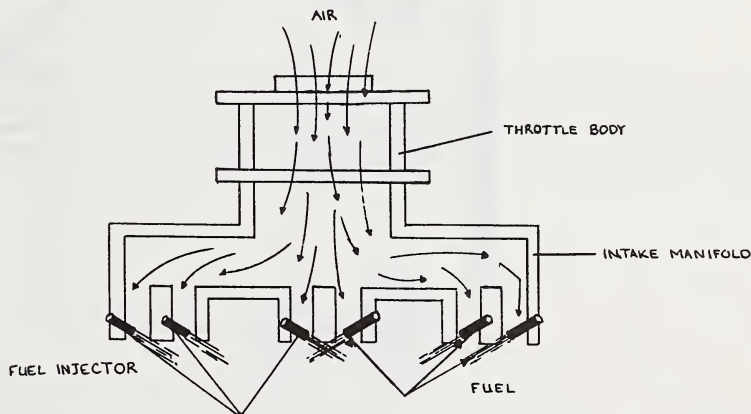
### (a) The carbureted fuel system (CFS)

Until just recently, gasoline engines used in automobiles have had carburetors in their fuel systems. The carburetor is a device which mixes air and gasoline vapor in the proper proportions to produce a highly combustible mixture. Air is drawn through the carburetor where it is mixed with vaporized gasoline and then is distributed to each cylinder through the intake manifold.



### (b) The fuel-injection system (FIS)

Until recently, the fuel-injection system was common only to diesel engines. However, now many gasoline automobile engines are equipped with this type of system. In this system, the carburetor is replaced by a unit known as a throttle body. The throttle body controls only the amount of air flowing into the intake manifold. Attached to the intake manifold is a series of fuel injectors. A fuel-injector is a device that at the proper moment, sprays or injects a metered amount of gasoline into the intake manifold opposite the intake valve. When the intake valve opens, the gasoline and air enters the cylinder.



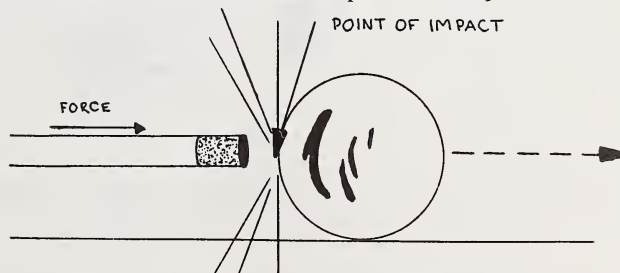
Remember, not all fuel-injection systems are of this type. Some systems have the fuel injectors spraying continuously, varying the amount of fuel to suit operating requirements. These systems will be described in detail later in the course.

## FORCE, ENERGY, WORK AND POWER

### 1. Force

Force may be defined as a push or pull that is exerted against an object. This push or pull may cause an object at rest to move, or an object already in motion to move faster, slower or change direction. We can say that everything that is moving was pushed or pulled by some force.

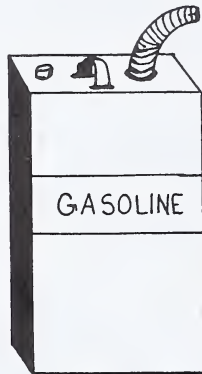
The unit for force is the **Newton (N)**. A force of one Newton will cause a mass of 1 Kilogram to move at a rate of one metre per second squared.



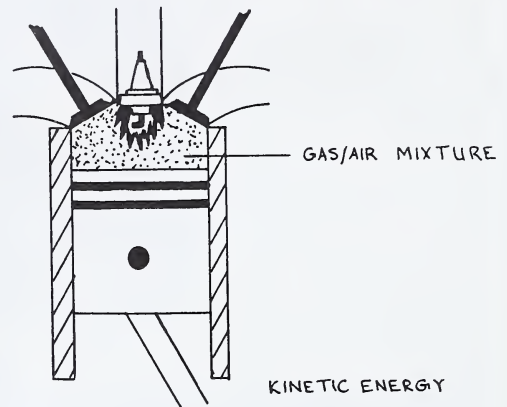
Force from the billiard cue causes the billiard ball to move away from the point of impact.

## 2. Energy

The dictionary defines energy as the potential or ability to do work. Energy is present in two basic forms: potential and kinetic. One can think of the gasoline stored in our car fuel tanks as potential energy due to its condition. Gasoline has the potential to release energy and do work for us. The combustion of the gasoline and air mixture in the cylinder is an example of kinetic energy. It has the ability to do work for us due to its motion.

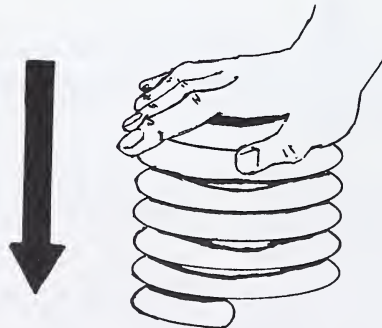


POTENTIAL ENERGY



## 3. Work

When energy is put to a useful purpose, we say that work is being done. Work is done only when the object is moved by the application of a force. When a coil spring is compressed, work is done on the spring.



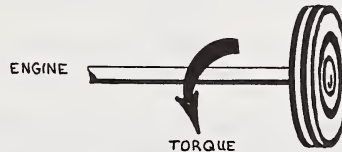
Work and energy are measured in **joules (J)**. A joule is the force of one newton applied through a distance of one meter (**1J = 1 N•m**). Therefore, work and energy can be defined as force times distance.

#### 4. Power

Work can be done very slowly, or it can be done very quickly. The rate at which work is done is known as **power**. Power is measured in **watts (W)**. One watt is equal to one joule of energy per second (**1W = 1J/s**).

#### 5. Torque

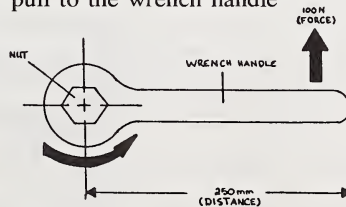
So far in this course power has been described in terms of straight motion. However, there are situations, such as in engines, where the power output is rotational. This rotational, a turning force or effort is known as **torque**. To loosen the lid of a screw top jar you apply torque much the same as the engine of a car applies torque to the wheels to make them rotate.



Torque is a twisting force.

Do not confuse torque with power. Torque is a twisting force which may or may not result in motion. Power, however, is the rate at which work is being done, and this means that something must be moving.

Torque is measured in newton metres (**N•m**) and acts perpendicular to the axis. For example, suppose you wanted to loosen a rusted nut on a bolt using a wrench. Let us assume that you were to apply a pull-force of 100N on the wrench and suppose that the center of the nut to the end of the wrench handle was 250 mm or 0.250 m long. The amount of torque is calculated by multiplying force times distance (**T = F × D**). You would be applying  $100\text{N} \times 0.250\text{ m} = 25\text{ N•m}$  of torque to the nut regardless of whether or not the nut was turning. The torque is there as long as you continue to apply the 100N pull to the wrench handle



$$\begin{aligned}\text{Torque} &= \text{Force} \times \text{Distance} \\ &= 100\text{N} \times (250 \div 1000)\text{ m} \\ &= 25\text{ N•m}\end{aligned}$$

**NOTE:** The joule, also symbolized **N•m**, measures force applied through distance, and not perpendicular to it as in torque.

## ENGINE MEASUREMENTS AND PERFORMANCE

### 1. Engine Power

Until recently engine performance was measured in horsepower. Today, we still measure engine performance in terms of power, however, the unit we use is the **watt**. The watt measures the amount of work done over a period of time. In units, one watt equals one joule of energy or work expended per second ( $W = 1 \text{ J/s}$ ).

For example, an engine rated at 50 kW would be capable of doing 50 kJ of work every second it was operating. If a vehicle must be moved 1000 m with a force of 500 N in 10 seconds we can determine the size of engine required as follows:

$$\begin{aligned} 1 \text{ J} &= 1 \text{ N} \cdot \text{m} \\ &= 500 \text{ N} \times 1000 \text{ m} \\ &= 500\,000 \text{ J} \end{aligned}$$

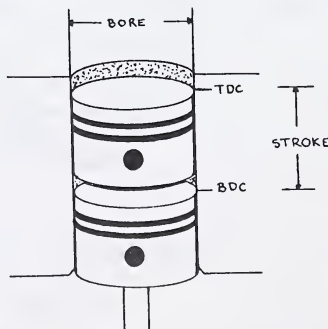
$$\begin{aligned} 1 \text{ W} &= 1 \text{ J/s} \\ \text{Power Required} &= 500\,000 \text{ J} \div 10 \text{ seconds} \\ &= 50\,000 \text{ W} \\ &= 50 \text{ kW} \end{aligned}$$

Engine ratings are determined at their peak running efficiency under optimum conditions. Since our engine would be operated under adverse conditions, we would probably use a larger engine to meet the requirements. Most engines used in automobiles are rated at between 50 to 230 kW.

Many factors determine the ability of an engine to produce usable power. The engine manufacturer uses the following engine measurements to satisfy the performance requirements for a certain application.

### 2. Bore and Stroke

The term **bore** is used to describe the diameter of a cylinder. The **stroke** is the distance the piston travels from bottom dead center (BDC) to top dead center (TDC). Bore and stroke are used to indicate the size of an engine cylinder. When the size of a cylinder is indicated, the bore is always mentioned first. In a 100 mm  $\times$  90 mm cylinder, the bore is 100 mm and the stroke is 90 mm. Both measurements are used to calculate piston displacement.



Pre 1955 engines were built with a long stroke and small bore. Recent engines have been designed with a shorter stroke and a larger bore. One late model 53 kW Volkswagen engine has a 79.5 mm bore and a 73.4 mm stroke. An engine such as this is called “oversquare”. A bore and stroke of equal lengths is a “square” engine.

There are several advantages to the oversquare engine. A shorter piston stroke:

- (a) reduces friction loss
- (b) reduces piston ring wear
- (c) reduces the loads on engine bearings
- (d) reduces the engine height allowing for a lower hoodline.

### 3. Piston Displacement

Piston **displacement** is a measurement of size. It is equal to the number of cubic centimeters ( $\text{cm}^3$ ) the piston displaces as it moves from BDC to TDC. For an engine with more than one cylinder, it is necessary to multiply the displacement of one cylinder by the number of cylinders.

For example, calculate the total displacement of a six cylinder engine with a cylinder bore of 100 mm and a stroke of 90 mm.

$$\begin{aligned}\text{Engine Displacement} &= \text{Area of Bore} \times \text{Stroke} \times \text{Number of Cylinders} \\ &= \pi (\text{radius of the bore})^2 \times 90 \text{ mm} \times 6 \\ &= 3.1416 \times (50 \text{ mm})^2 \times 90 \text{ mm} \times 6 \\ &= 4241160 \text{ mm}^3 \\ &= 4241 \text{ cm}^3 \text{ approximately}\end{aligned}$$

Displacement in automobiles is usually given in litres, therefore it is necessary to divide  $4241 \text{ cm}^3$  by  $1000 \text{ cm}^3$  ( $1 \text{ L} = 1000 \text{ cm}^3$ ), or  $4241 \div 1000 = 4.24 \text{ L}$ .

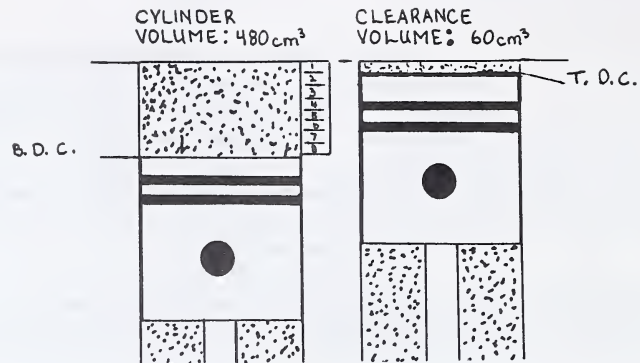
The engine's ability to produce varying amounts of power depends very much on the engine size or displacement. Engines with greater displacement are able to draw in a greater amount of air-fuel mixture with each intake stroke and can therefore produce more power. Three ways of increasing engine displacement are: increasing cylinder bore diameter, lengthening the piston stroke, and by increasing the number of cylinders.

### 4. Compression Ratio

The **compression ratio** of an engine is the comparison between the air volume of the whole cylinder (with the piston at BDC) to the air volume of the small space at the top of the cylinder (with the piston at TDC). The air volume with the piston at TDC is called the **clearance volume**. The compression ratio is calculated by:

$$\text{Compression Ratio} = \text{Cylinder Volume} \div \text{Clearance Volume}$$

For example, the engine of one car has a cylinder volume of  $480 \text{ cm}^3$  at BDC and has a clearance volume of  $60 \text{ cm}^3$  at TDC. The compression ratio is  $480 \div 60$  or  $8.0/1$ , usually written as  $8.0:1$ . In other words, the air-fuel mixture is compressed from a volume of  $480 \text{ cm}^3$  to  $60 \text{ cm}^3$ ;  $\frac{1}{8}$  of its original volume during the compression stroke.



Compression Ratio 8 to 1

The compression ratio of an engine can be raised or lowered. To raise the compression ratio, the clearance volume can be reduced and the cylinder volume left unchanged, or the cylinder volume can be increased (increase the bore or stroke) and the clearance volume left unchanged. Thus, to lower the compression ratio, increase the clearance volume, leaving the cylinder volume unchanged. Another way is to reduce the cylinder volume (decrease the bore or stroke) and leave the clearance volume unchanged.

Increasing the compression ratio of engines has several advantages. An engine with a higher compression ratio compresses the air-fuel mixture more. This means higher pressures at the end of the compression stroke and during the power stroke as well. This results in more push on the piston for a larger part of the power stroke. Thus, more power is obtained from each power stroke and the economy of the engine is increased.

Some special problems are associated with increasing the compression ratio of engines. As the compression ratio increases, detonation or "knocking" becomes a problem. Detonation is when the fuel mixture ignites (due to high temperatures caused by high pressures) before the spark occurs at the spark plug. This produces very rapid and uncontrolled burning which can seriously damage an engine.

Higher compression engines also have a tendency to produce excessive amounts of nitrogen oxide (NOx), a serious atmospheric pollutant. The formation of NOx is due to the higher combustion temperatures associated with the higher compression engines. Prior to the more strict emission-control legislation, compression ratios were at approximately 12:1. This resulted in good power production but very high exhaust emissions. Therefore, compression ratios today range anywhere from 8.5:1 to 10.5:1. Further discussion will follow in the lesson on vehicle exhaust emissions. As discussed in the previous lesson, diesel engines use higher compression ratios. They use a different fuel and a fuel injection system which help to eliminate detonation and causes less harmful exhaust emissions.

## ENGINE EFFICIENCY

Engine efficiency is the relationship between the actual power delivered by the engine and the power that could be obtained without any power loss. There are three types of engine efficiency.

### 1. Volumetric Efficiency

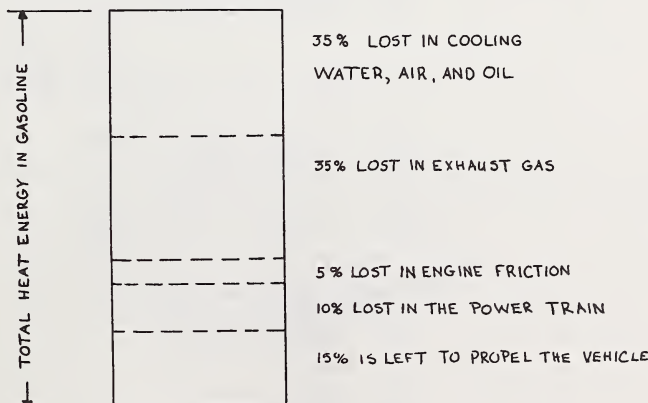
Volumetric efficiency is the amount of air-fuel mixture an engine is able to take in on the intake stroke compared to filling the cylinder completely. If the fuel-air mixture were drawn into the cylinder very slowly, the cylinder could be completely filled. However, the mixture must pass very rapidly through the narrow opening and bends on its way from the carburetor to the intake valve. The heat from the engine expands this mixture. Therefore, a full charge cannot enter the cylinder because the time is too short and because the air becomes heated.

Volumetric efficiency is given as a percentage of what actually enters the cylinder to what could enter the cylinder to completely fill it. Higher engine speeds greatly reduce volumetric efficiency. In fact, in some engines the volumetric efficiency may drop to as low as 50% at high speeds. This means that the cylinders are only "half filled" at high speeds.

In order to improve volumetric efficiency, intake valves can be made larger, the number of valves per cylinder can be increased, a shorter, straighter and wider passaged intake manifold can be used, and the use of carburetors with larger air passages. Turbo charging is often used to cram a greater amount of fuel-air mixture into the cylinders. In fact, near 100% volumetric efficiency has been achieved with the use of turbo chargers.

### 2. Thermal Efficiency

Thermal efficiency is the ability of an engine to convert the heat energy produced by the fuel. In gasoline engines, approximately 35% of the heat energy produced is lost through the exhaust, another 35% is absorbed by the cooling system which dissipates to the atmosphere, and the remaining 30% is used to produce power. Of this 30%, an additional 5% is lost in engine friction with another 10% lost in the power train. This leaves only 15% to propel the vehicle.



Due to the large amount of heat lost during engine operation, thermal efficiencies may be as low as 20% and seldom higher than 25%.

### 3. Mechanical Efficiency

Mechanical efficiency refers the amount of power that is developed in the cylinders that is delivered or usable. This amount is indicated as a percentage.

$$\text{Mechanical Efficiency} = \text{Output Power} \div \text{Input Power}$$

For example, at a certain speed the output power is 116 kW and the input power is 135 kW. The mechanical efficiency is,  $116 \div 135 = 0.86$ , or 86%. 86% of the power developed in the cylinders is delivered by the engine and the remaining 14% (19 kW) is consumed as friction power.

Through the previous discussion, we can see that at every step in the process, from the burning of the gasoline in the cylinders to the rotation of the wheels, energy is lost. The overall efficiency is quite low, as little as 15% of the energy in gasoline remains to actually propel the car. This energy is used to overcome the rolling resistance of the wheels, air resistance, and to accelerate the car.

### SELF-CORRECTING EXERCISE 1

Choose the letter of the **best** answer and place it in the blank to the left of the question.

- \_\_\_\_\_ 1. Engine classification is dependent on
- (a) engine size.
  - (b) engine stroke cycle.
  - (c) engine stroke and bore.
  - (d) engine design.
- \_\_\_\_\_ 2. The most common valve arrangement is the
- (a) L-head arrangement.
  - (b) I-head arrangement.
  - (c) T-head arrangement.
  - (d) F-head arrangement.
- \_\_\_\_\_ 3. An engine with its cylinders arranged one behind the other is known as
- (a) an opposed-piston design.
  - (b) a V-type design.
  - (c) an in-line design.
  - (d) a two-stroke cycle engine.
- \_\_\_\_\_ 4. Stored energy is called
- (a) potential energy.
  - (b) energy of motion.
  - (c) force.
  - (d) kinetic energy.

- \_\_\_\_\_ 5. The energy of movement is called \_\_\_\_\_ energy.
- (a) potential
  - (b) kinetic
  - (c) rotational
  - (d) torque
- \_\_\_\_\_ 6. The unit of force is the \_\_\_\_\_.
- (a) joule
  - (b) watt
  - (c) kilowatt
  - (d) newton
- \_\_\_\_\_ 7. An engine with a larger bore measurement than a stroke measurement is called \_\_\_\_\_.
- (a) oversquare
  - (b) overshot
  - (c) square
  - (d) high performance
- \_\_\_\_\_ 8. The total displacement of a four cylinder engine with a cylinder bore of 79.4 mm and a stroke of 73.4 mm is approximately \_\_\_\_\_ litres.
- (a) 0.15
  - (b) 150
  - (c) 1.5
  - (d) 1500
- \_\_\_\_\_ 9. Out of the total heat energy in gasoline, \_\_\_\_\_ is left to propel the vehicle.
- (a) 30%
  - (b) 15%
  - (c) 35%
  - (d) 60%
- \_\_\_\_\_ 10. One disadvantage to increasing the compression ratio of an engine is
- (a) higher pressures within the cylinder.
  - (b) detonation of the fuel mixture increases.
  - (c) economy of the engine is decreased.
  - (d) a reduction in NOx gas occurs.

**SELF-CORRECTING EXERCISE 2****True or False**

1. Volumetric efficiency increases with engine speed. (True or False) \_\_\_\_\_
2. Turbo charging engines increases volumetric efficiency. (True or False) \_\_\_\_\_
3. Mechanical efficiency equals input power divided by output power. (True or False)  
\_\_\_\_\_
4. Fuel injection systems do not use a carburetor to mix the fuel and air. (True or False)  
\_\_\_\_\_
5. Engine power is rated in kW. (True or False) \_\_\_\_\_

Send the following exercises in for correction.

### EXERCISE 1

1. Define energy and work. In what unit are they measured?

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2. Define torque. In what unit is it measured?

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3. Sometimes torque is confused with power. How does torque differ?

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4. What do the terms bore and stroke describe?

---

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5. Why are many modern engines made “over square”?

---

---

---

---

6. Explain volumetric efficiency.

---

---

7. How is compression ratio calculated?

---

---

8. List eight ways in which engines may be classified.

- (a) \_\_\_\_\_
- (b) \_\_\_\_\_
- (c) \_\_\_\_\_
- (d) \_\_\_\_\_
- (e) \_\_\_\_\_
- (f) \_\_\_\_\_
- (g) \_\_\_\_\_
- (h) \_\_\_\_\_

## EXERCISE 2

### Problems

1. Suppose you were to apply 150 N of force to the handle of a torque wrench 350 mm long in order to properly torque the cylinder head bolts of an engine. How much torque would you be applying?

2. Calculate the total displacement in  $\text{cm}^3$  of an eight cylinder engine with a cylinder bore of 100 mm and a stroke of 90 mm.
3. Calculate the compression ratio of an engine with a cylinder volume of  $560 \text{ cm}^3$  at BDC and a clearance volume of  $60 \text{ cm}^3$  at TDC.

**ANSWERS TO SELF-CORRECTING EXERCISES****Self-Correcting Exercise 1**

- |               |                 |
|---------------|-----------------|
| 1. d (page 1) | 6. d (page 5)   |
| 2. b (page 3) | 7. a (page 9)   |
| 3. c (page 3) | 8. c (page 9)   |
| 4. a (page 6) | 9. b (page 11)  |
| 5. b (page 6) | 10. b (page 10) |

**Self-Correcting Exercise 2**

1. False (page 11)
2. True (page 11)
3. False (page 12)
4. True (page 5)
5. True (page 8)

**END OF LESSON 2**

# LESSON RECORD FORM

1746 Mechanics 12  
Module 1

## FOR STUDENT USE ONLY

Date Lesson Submitted

(If label is missing  
or incorrect)

File Number

Time Spent on Lesson

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## PISTON ENGINE CONSTRUCTION

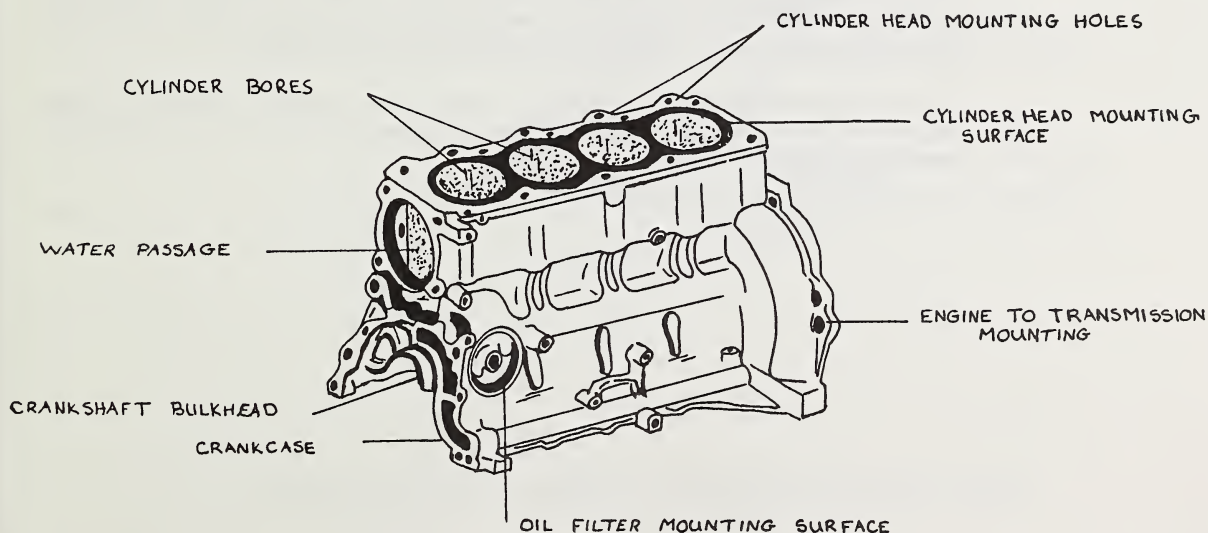
Introduction  
Cylinder Block  
Cylinder Head  
Crankshaft  
Pistons, Rings and Connecting Rods  
Valves and Valve Train

### INTRODUCTION

In earlier lessons we looked at the basics of engine operation as well as engine types. We have discussed how the fuel-air mixture is delivered by the fuel system to the engine cylinders. In the cylinders it is compressed, ignited, and burned. The burning stage produces the high pressure that pushes the piston down so the crankshaft turns and the engine can produce power. In this lesson we shall look at the construction of the automotive engine in detail.

### CYLINDER BLOCK

The cylinder block is the foundation of the engine as everything else is either put inside the block or attached to it. Its major function is to provide a strong, unmoveable mounting that keeps the internal moving parts in exact alignment.



CYLINDER BLOCK FOR A FOUR-CYLINDER, IN-LINE ENGINE

This function, however, is not easily accomplished. The cylinder block is constantly subjected to extreme changes in the environment in which it operates. For example, its average metal temperature on a cold Alberta morning will change from  $-30^{\circ}\text{C}$  to  $107^{\circ}\text{C}$  in only a few minutes. Along with this, internal pressures from lubricants, coolants, and those from combustion gases apply extremely great force inside. The movement of the crankshaft and pistons add to the already great stresses on the block.

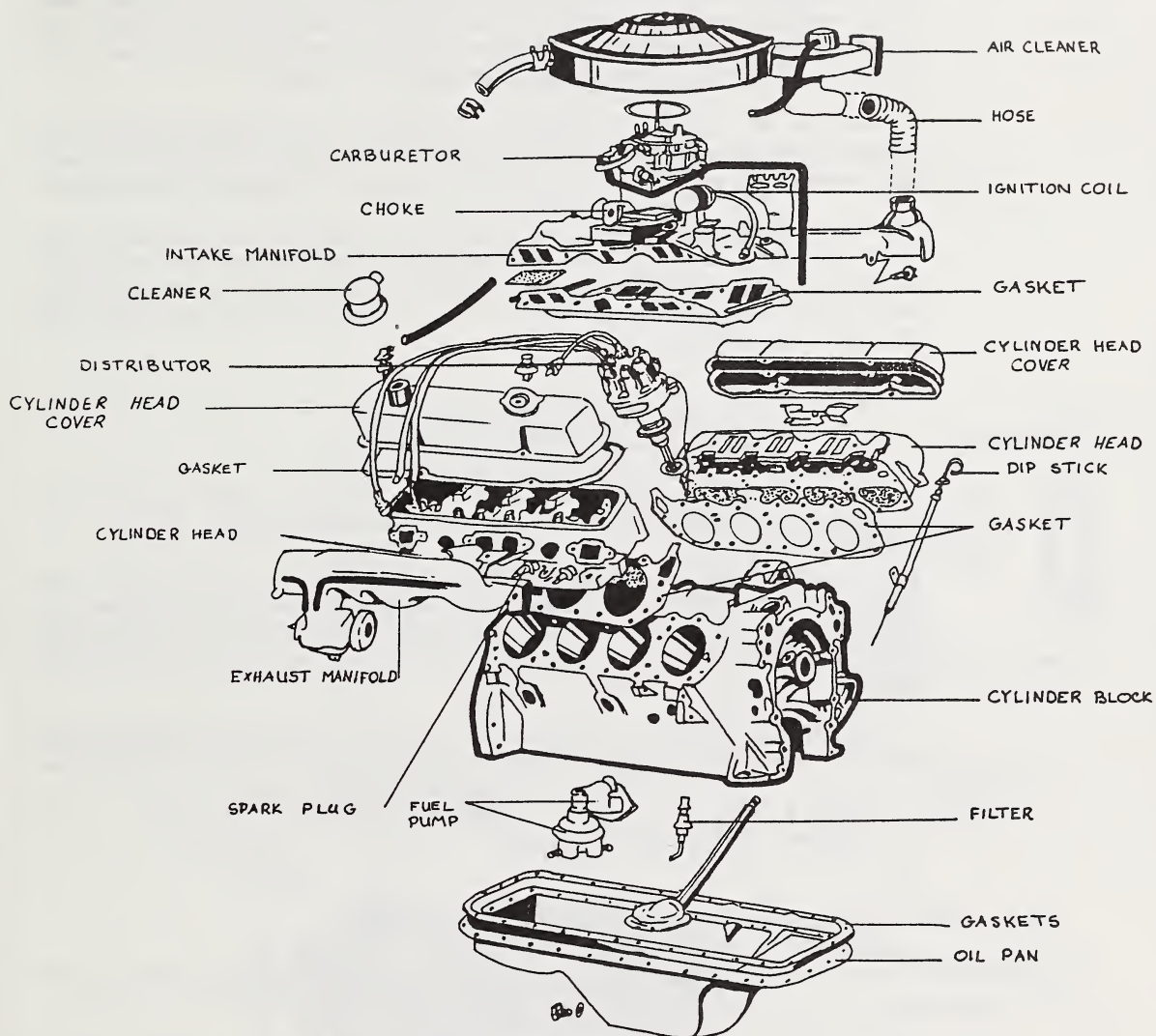
To design a cylinder block that will withstand these forces is no small accomplishment. Yet on the average, the block has a longer service life than any other part of a modern engine.

The cylinder block is cast in one piece from various metals. One metal used is gray iron which is mixed with nickel or chromium. These added metals give the cylinder block greater strength as well as greater resistance against wear. Cast iron blocks are usually quite heavy. Thus, most modern day manufacturers of four cylinder engines produce cylinder blocks cast from lighter weight aluminum.

Regardless of which metal is used, the cylinders, cooling jackets, and crankshaft bearing supports are all built into one large metal part. The cylinders are large holes in the block that guide the pistons. Surrounding the cylinders are spaces through which coolant (water and antifreeze) flows. These spaces are known as "water jackets." The coolant flowing through the water jackets absorbs heat and carries it to the radiator where the heat is released to the air. Crankshaft bearing (also known as main bearing) mounts are molded into the bottom of the block at specially designed bulkheads. The bulkheads are ribbed in order to reinforce the block and properly distribute the forces coming from the crankshaft.

The top of the block is machined flat so that the cylinder head(s) can be mounted. Along with the cylinder head covers, the intake and exhaust manifolds, the carburetor and other related parts are also mounted. The oil pan is attached to the bottom of the engine block. The bottom of the block, together with the oil pan, form the crankcase. The crankcase encloses the crankshaft and is the holding tank for the engine oil. When the engine is running, the oil pump sends oil from the oil pump up through passage ways in the block to lubricate the moving parts. The oil pan, as with most attached parts, have either a gasket or seal in the joint between them thus creating a leakproof seal between the parts.

The cylinder block of gasoline and diesel engines look much alike. However, the diesel engine block is much heavier and stronger due to the higher compression ratio and combustion pressure involved.



External parts which are attached to the cylinder block (V-8 engine)

The crankshaft bearings, often called the main bearings or "mains", are of the split type. The upper halves fit into the half round bulkhead sections in the block. The lower halves fit into bearing caps which are attached to the block by means of cap screws. Each cap is bored to match a particular spot in the block. Therefore, when the caps are removed for some reason they must be returned to the same place and position.

The flywheel is attached to the rear of the crankshaft. Following the installation of the crankshaft, the pistons with their piston rings and connecting rods are installed in the block. The connecting rods are fastened to the crankshaft by bearings and caps with rod bolts and nuts.

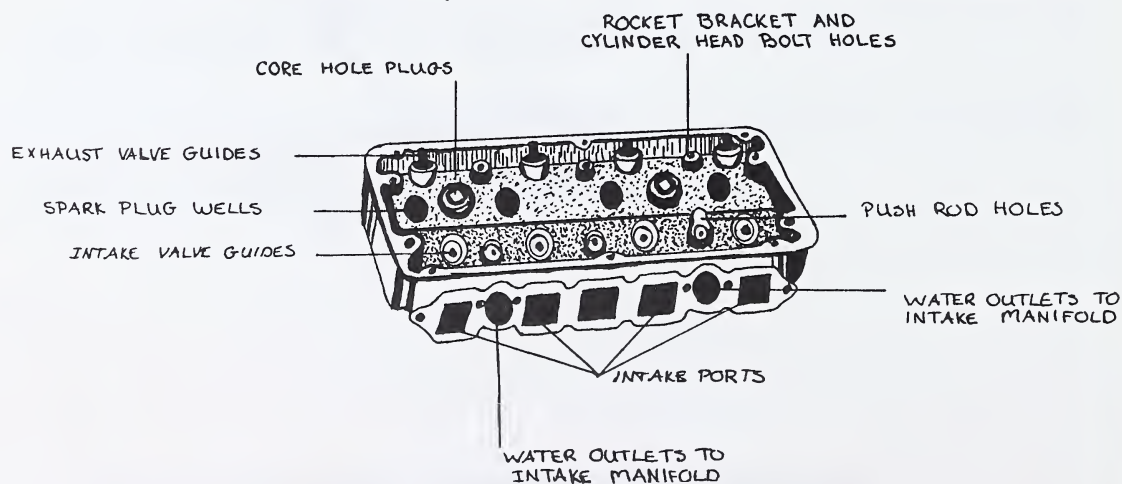
These parts, when assembled into the cylinder block, make up an assembly called a "short block." The short block is a service item that can be purchased to solve a service problem such as worn cylinder bores, damaged block or main bearings, etc. The rest of the old engine parts, including the head and manifolds are then installed on the new short block. (See illustration on page 5).

## CYLINDER HEAD

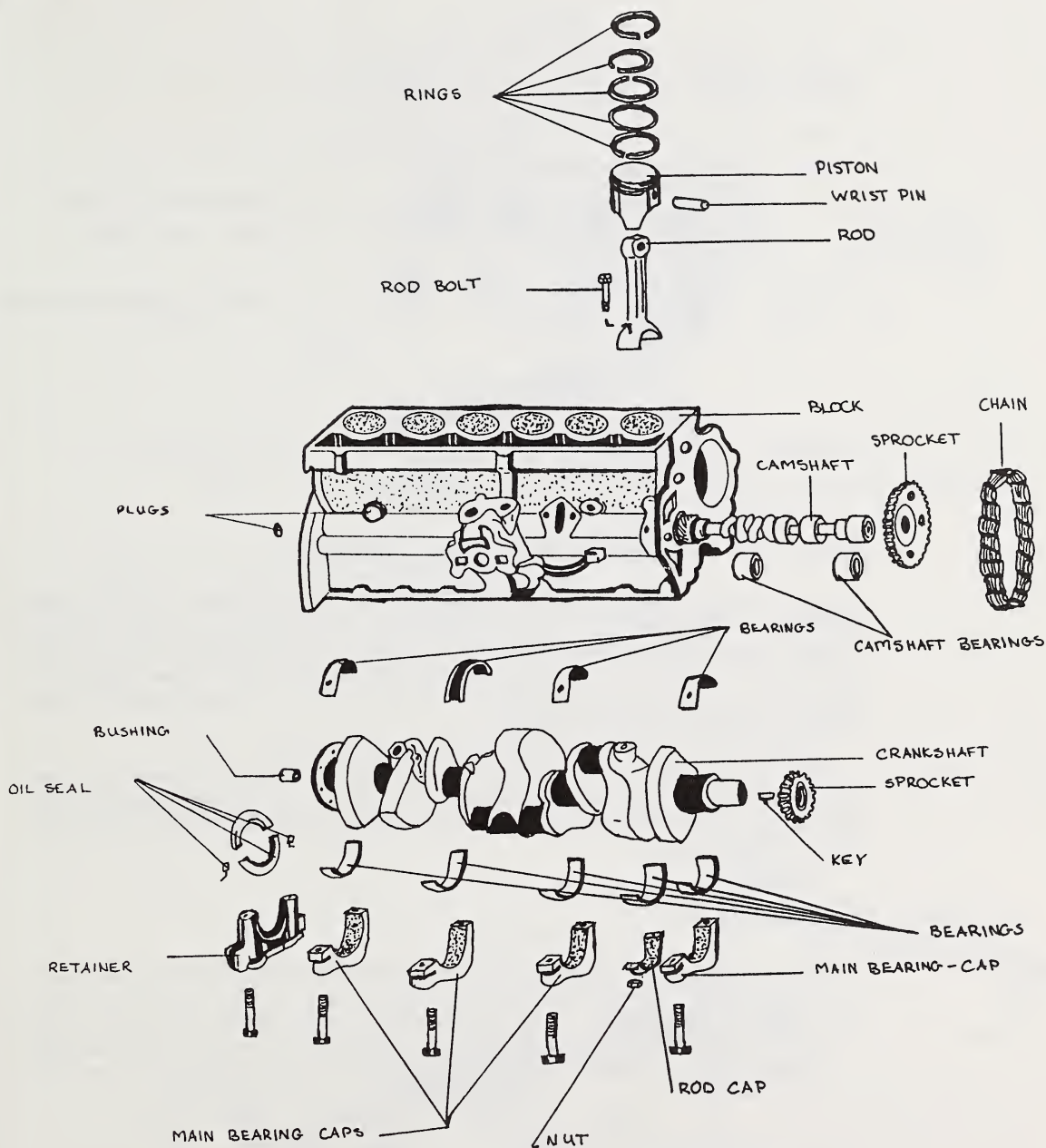
The cylinder head is attached to the top of the cylinder block. The head encloses the engine cylinders and forms the upper end of the combustion chambers.

The cylinder head is cast in one piece. Most cylinder heads are cast from iron or iron alloyed with other metals. In order to decrease engine weight, some cylinder heads are made of an aluminum alloy. Another advantage of an aluminum head is that the aluminum carries the heat away from the hot areas more readily. This is extremely important in high performance engines.

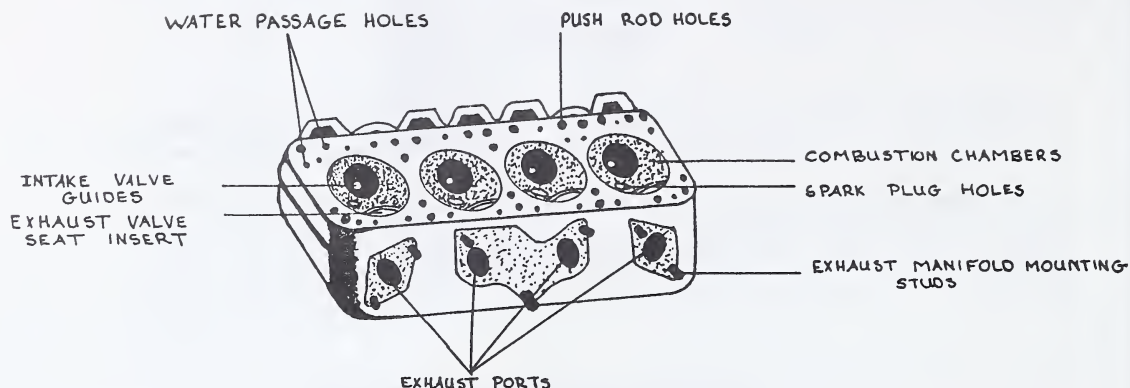
Also included in the cylinder head are water jackets and passages which lead to the intake and exhaust manifolds. The cylinder head also houses the intake and exhaust valve assemblies.



Top View of A Cylinder Head (V-8 overhead-valve engine)



Internal parts which are enclosed in the cylinder block (six-cylinder engine) forming what is called a "short block."



Bottom View of A Cylinder (V-8 overhead-valve engine)

Three general types of cylinder heads are used for gasoline engines: L-head, I-head, and single overhead camshaft (SOHC). L-heads were used in antique cars and are still used in small engines, such as those used in lawn mowers. The I-head design (with the valves in the head) is the type of head used in most modern engines. Many I-head engines have the camshaft on the cylinder head (SOHC). They may even use two camshafts on the head (double overhead camshaft or DOHC).

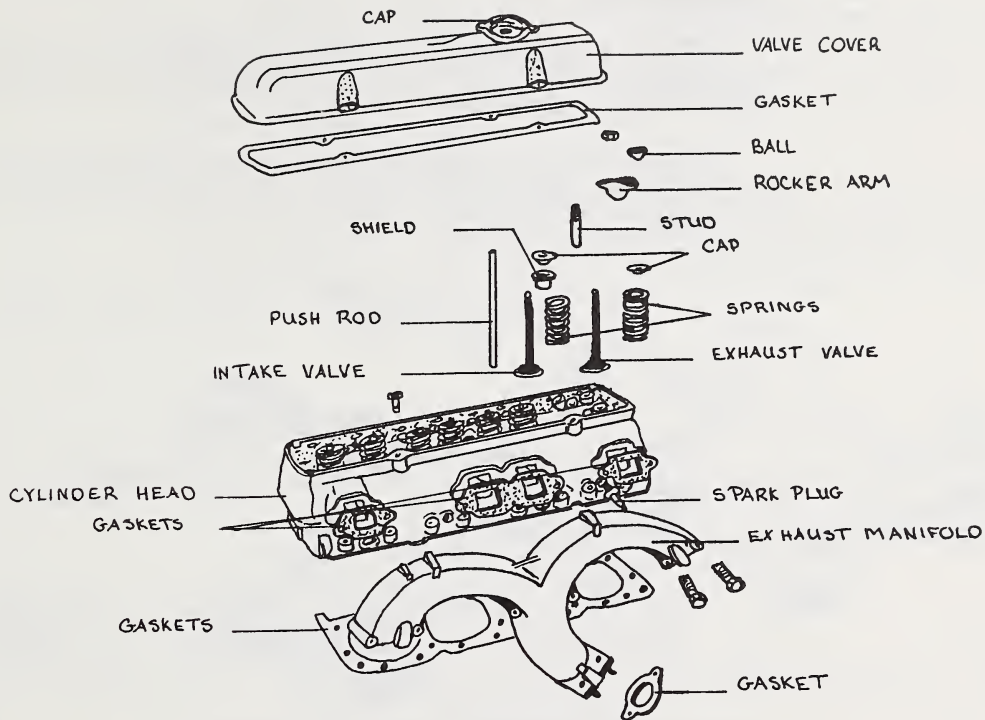
Some engine manufacturers are using cylinder heads with additional features that increase engine performance. These additional features include a turbulence generating pot (TGP) that produces high turbulence of the air-fuel mixture during combustion, and also may include additional intake valves.

### 1. Head Gaskets

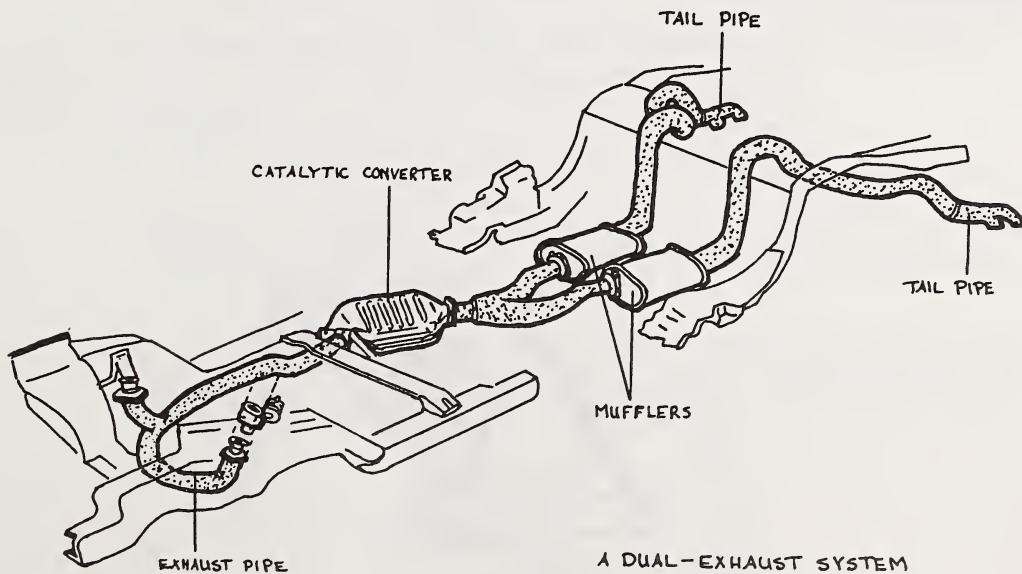
The joint between the cylinder block and cylinder head must withstand the pressure and heat developed in the combustion chambers. In order to provide the necessary tight seal a head gasket is used. Head gaskets are made of thin sheets of soft metal or may be a combination of soft metal and asbestos. The gasket has all of the necessary openings cut out. When it is installed, tightening the head bolts squeezes the soft metal and seals the joint tightly.

### 2. Exhaust Manifold

The exhaust manifold carries the exhaust gases away from the cylinder head and toward the exhaust system. It consists of a set of tubes which are bolted to the side of the head. The other end of the exhaust manifold is attached to the exhaust pipe which includes a muffler to reduce engine noise and may include a catalytic converter. Catalytic converters reduce the amount of pollutants coming out of the tail pipe.



Parts Attached to the Cylinder Head of a V-8 Engine

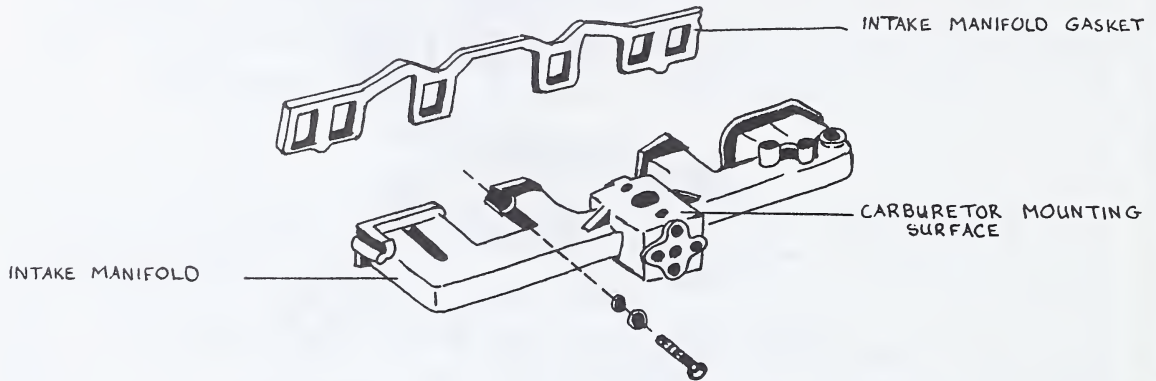


A Dual-Exhaust System With Single Catalytic Converter

### 3. Intake Manifold

The intake manifold is a set of tubes that distribute the fuel-air mixture from the carburetor through the cylinder head to each combustion chamber. The carburetor is mounted to the intake manifold.

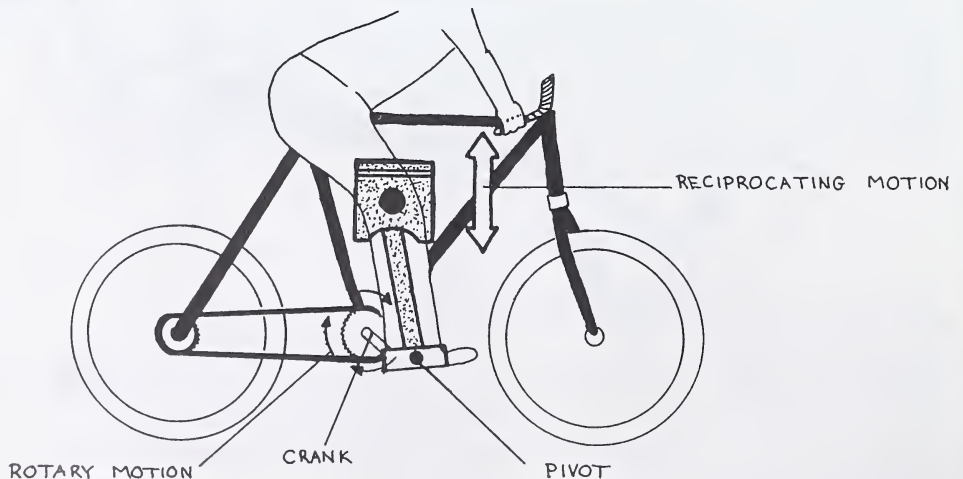
The intake manifold is mounted on the same side of the cylinder head as the exhaust manifold on in-line engines. On V-4, V-6, and V-8 engines the intake manifold is mounted between the two cylinder heads.



Intake Manifold For A Six-Cylinder In-Line Engine

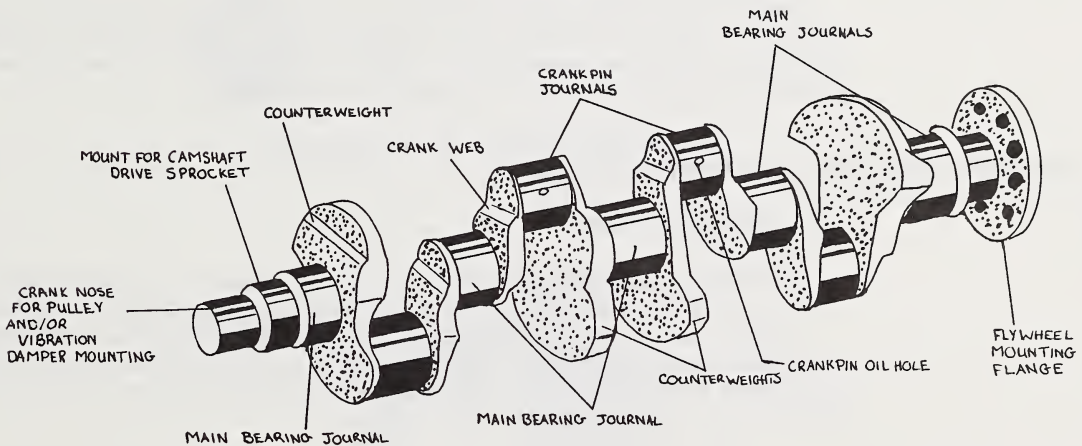
### CRANKSHAFT

As we learned earlier, one of the major functions of the cylinder block is to provide solid support for the crankshaft. The purpose of the crankshaft is to convert the up and down motion produced by the pistons into rotary motion. This conversion can be compared to the pedaling of a bicycle. The up and down (reciprocating) motion of your legs on the pedals is converted by the cranks attached to each pedal into rotary motion.



The crankshaft passes power and torque to the transmission. It must be strong enough to take the tremendous downward push of the pistons during the power strokes without twisting. In addition, the crankshaft must be carefully balanced to eliminate undue vibration since it may revolve at more than 6000 times per minute (designated r/min or  $\text{min}^{-1}$ ) at top engine speeds. To provide balance, crankshafts have counterweights opposite the cranks.

The crankshaft has three major parts: main bearing journals, crankpins, and crank webs. The entire shaft itself turns on the main bearing journals, which in turn ride in the main bearings of the engine block. The connecting rods and bearings are attached to the crankpins. The crankpins and the main journals are joined by the crank webs which also serve as balance weights for smooth engine running.

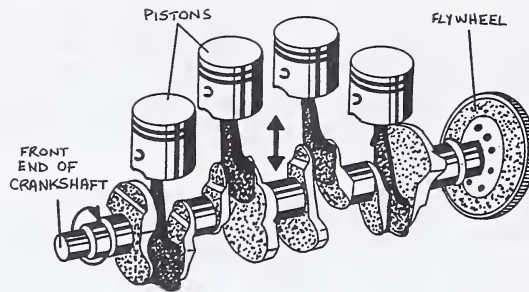


Usually, the crankpins are arranged to deliver the pulses of the pistons at even intervals. These intervals vary according to the number of cylinders; every 180 degrees of shaft rotation for a four cylinder engine, every 120 degrees for a six cylinder and every 90 degrees for a V-8 engine. The reason why a V-8 engine tends to run more smoothly than a four or six cylinder is the close spacing of its power impulses.

## 1. Flywheel

Even though the engine power impulses may overlap, there are still times when more power is being produced and times when less power is being produced. To smooth out the flow of power from the engine cylinders a flywheel is bolted to one end of the crankshaft. As the crankshaft tries to speed up, the flywheel absorbs energy and gives back energy as the crankshaft tries to slow down.

The flywheel is a heavy iron or steel disc with gear teeth around its outer rim (ring gear). The gear teeth mesh with the starting motor gear for cranking the engine. On manual transmission engines, the rear face of the flywheel serves as a driving member for the clutch.



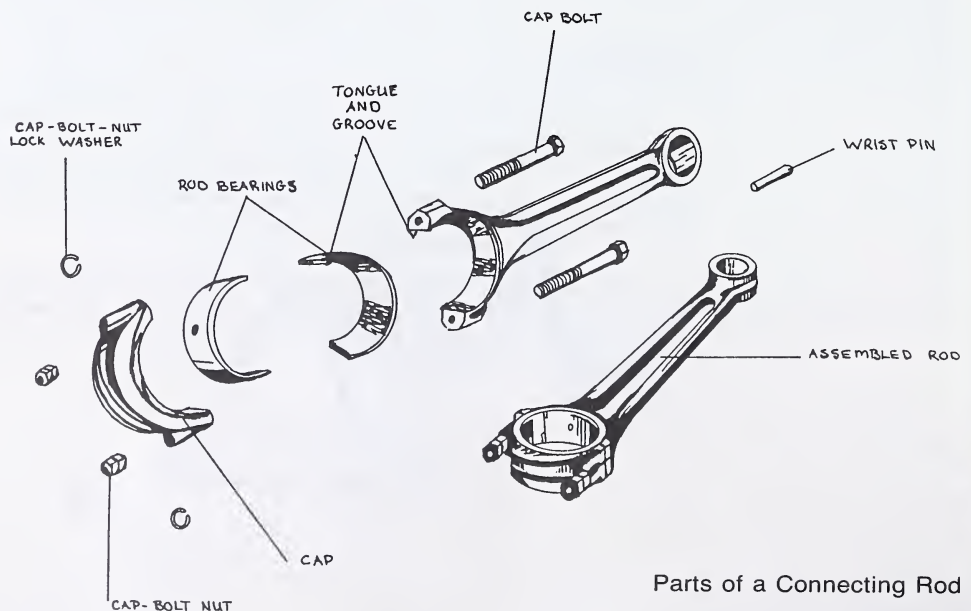
Attached to the front end of the crankshaft is a gear or sprocket that drives the camshaft, the vibration damper that further reduces power flow variations, and the drive-belt pulleys. These pulleys may drive the engine fan, water pump, alternator, power steering pump, air conditioner compressor, and the air pump (if so equipped).

## PISTONS, RINGS AND CONNECTING RODS

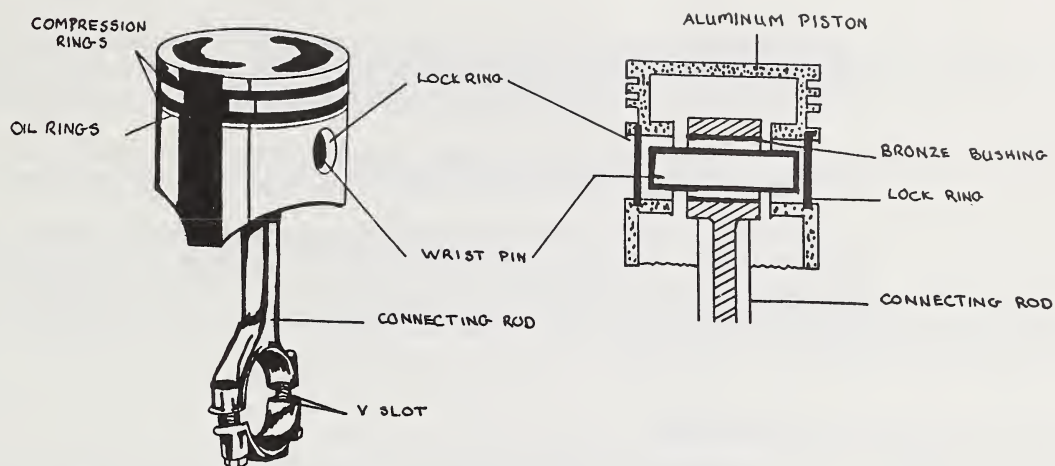
### 1. Connecting Rods

The connecting rod joins the crankshaft to the piston. It is attached at one end to the crankpin on the crankshaft and on the other end through a wrist pin to the piston. Since the connecting rod carries the power thrusts from the piston to the crankpin it must be very strong and rigid. Since the rod is in eccentric (off-center) motion, increased bearing load and vibration result. To minimize bearing loads and vibration, the rod is made of lightweight material.

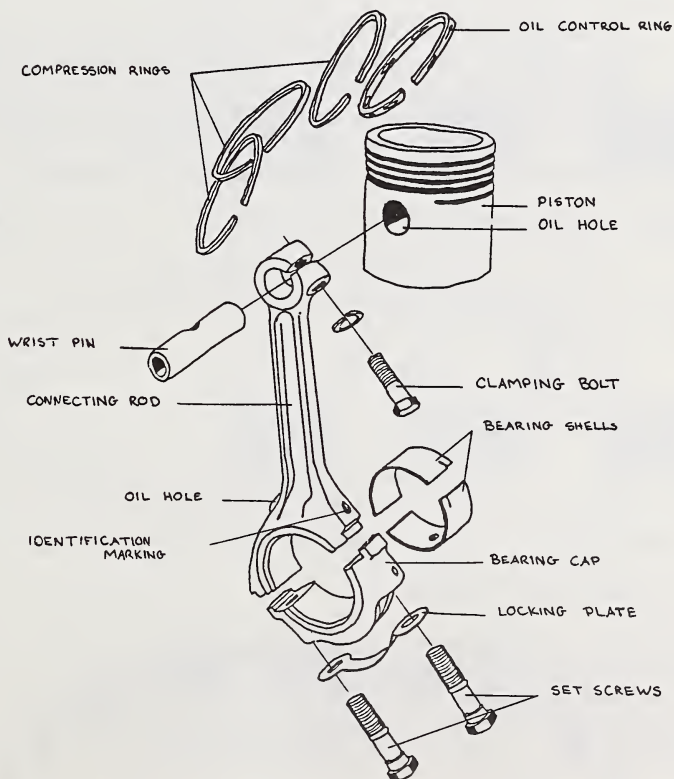
The big end of the connecting rod is attached to the crankpin by the rod caps and bolts. A split-style bearing is installed between the crankpin and the rod. The small end of the rod is attached to the piston by a hollow wrist pin. The pin passes through both the rod and the piston. The most common method of keeping the wrist pin in position is by a pair of lock rings which fit into grooves in the piston.



Parts of a Connecting Rod



Connecting Rod Attached to the Piston



A Connecting Rod That Clamps the Wrist Pin in Place

To lubricate the big-end bearing oil travels from the oil pump to oil lines (also called galleries) in the cylinder block to the main bearings. From here, oil travels through oil passages drilled in the crankshaft and through the connecting rod bearing holes onto the bearing surfaces.

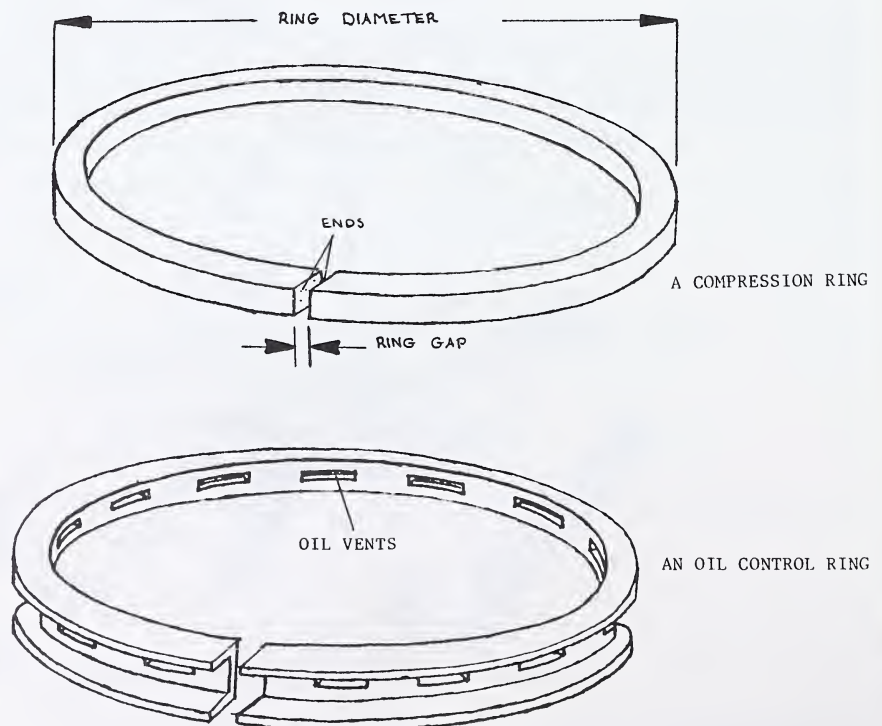
The wrist pins receive their lubrication from oil scraped from the cylinder walls by the piston rings. Some of this oil flows through slots in the piston to lubricate the pin.

Connecting rod caps and connecting rods are carefully matched during original assembly. The bearing bore is machined so that the cap will fit that rod and only that rod. During service jobs caps must not be interchanged. A cap on the wrong rod will not fit the crank on the crankshaft. Most caps contain a V-slot or other mark to aid in the correct assembly of this part to the rod.

## 2. Piston Rings

The piston is a cylindrical plug that moves up and down in the engine block. Each piston has piston rings to provide a good seal between the cylinder wall and piston. A good seal is necessary in order to prevent blow-by. Blow-by is the term used to describe the escape of unburned air-fuel mixture and burned gases from the combustion chamber, past the pistons, and into the crankcase.

The rings are installed in grooves located at the upper portion of the piston. There are two types of rings; compression rings and oil-control rings. Compression rings provide the seal during the compression and power strokes. The oil-control rings scrape excessive oil from the cylinder wall and return it to the oil pan. Most pistons contain at least two compression rings and one or two oil control rings. The rings are split so they can be expanded and slipped over the piston and into the grooves.



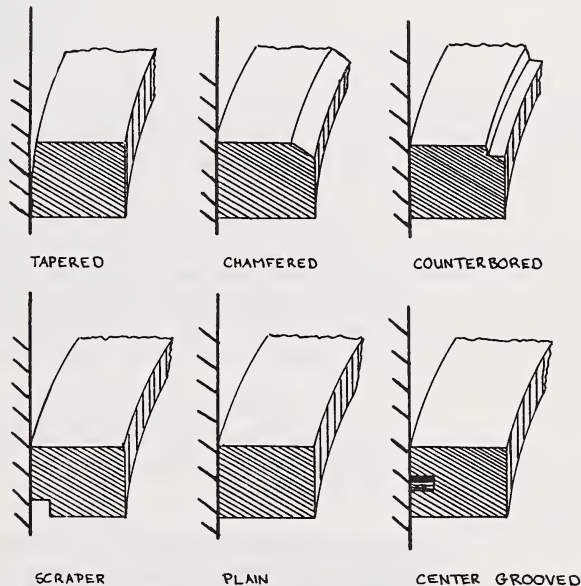
Piston rings are slightly larger in diameter than they will be when operating in the cylinder. The reason for the size difference is so that when they are installed they will press tightly against the cylinder wall.

Piston rings are fitted to the cylinder with enough end gap (clearance) to prevent the ends from touching when expanding by engine heat.

**(a) Compression Rings**

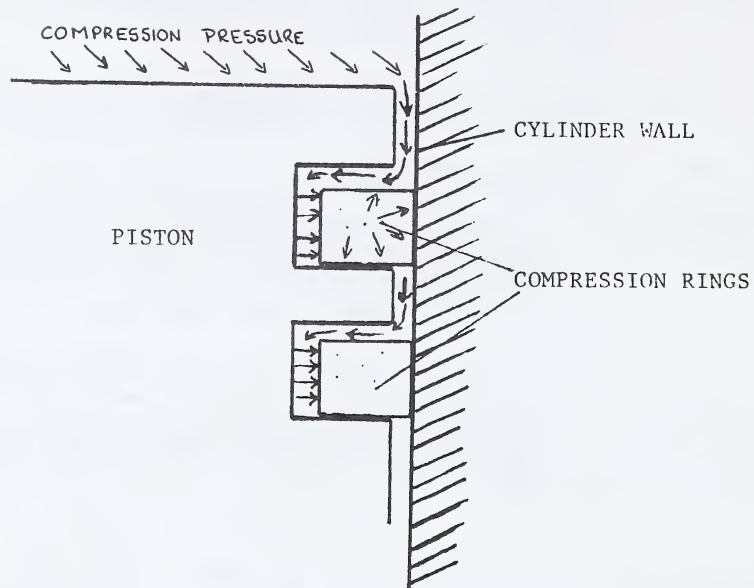
Compression rings are made of cast iron and in the past have been plated with chromium to reduce wear. Today's engines run at slightly higher temperatures. These temperatures can cause the chromium to melt, thus chromium plating has been replaced with a plating of molybdenum.

Usually, two compression rings are used so as to reduce the pressure on each one. Pressures inside the combustion chamber may reach 7000 kPa at the start of the power stroke. With two compression rings, the pressure in effect is divided between the two. This not only reduces blow-by, it also reduces the load on the upper ring.



Compression Ring Shapes

Compression pressure and combustion gas pressures are allowed to spill over the top of the compression ring and get behind it. The pressure then pushes the ring tightly against the lower edge of the ring groove and outward against the cylinder walls. Thus, the compression pressure and the combustion gases are contained by their own force.

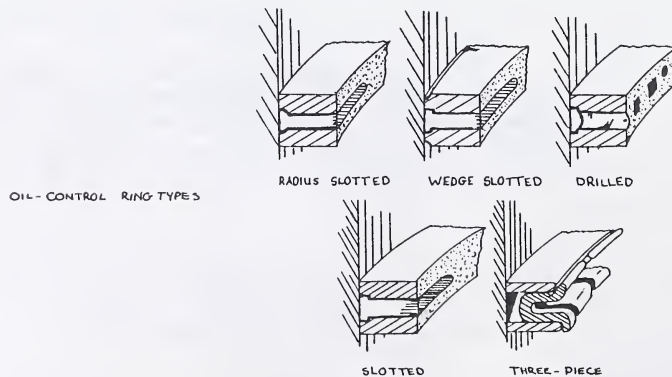


### (b) Oil-Control Rings

During engine operation, more oil is thrown onto the cylinder walls than is required. If an excess amount of oil is left on the cylinder walls, it makes its way up into the combustion chamber, where it burns. This increases oil consumption, fouls the spark plugs, and hampers the action of the compression rings. The oil control ring or rings scrape off the excess oil and return it to the oil pan thus preventing the oil from working up into the combustion chamber.

The oil that is scraped off carries particles of carbon, dust, and dirt. These particles are then removed from the oil by the oil filter. The oil also provides some cooling effect to the engine and also helps provide a seal between the rings and the cylinder wall.

Some oil-control rings are installed with an expander spring under them. The expander spring increases the pressure of the oil-control ring on the cylinder wall, improving its oil-scraping effect.



### 3. Pistons

#### (a) Parts of a Piston

##### (i) Piston Head

The piston head is the top part of the piston against which the combustion gases exert pressure. The shape of the piston head may be flat, concave, convex, or of irregular shape.

##### (ii) Land

The land refers to the area around the outside diameter of the piston, between the ring grooves and above the top ring.

##### (iii) Compression Ring Grooves

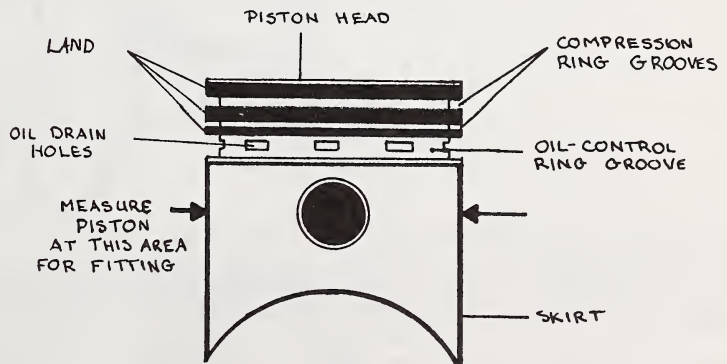
The compression ring grooves are cut into the upper part of the piston, around its circumference. Their depth depends on the piston size and types of rings used.

##### (iv) Oil-Control Ring Groove

The oil ring groove is the lowest and usually the widest groove cut into the piston. This groove generally has holes or slots for oil drainage to the interior of the piston.

##### (v) Skirt

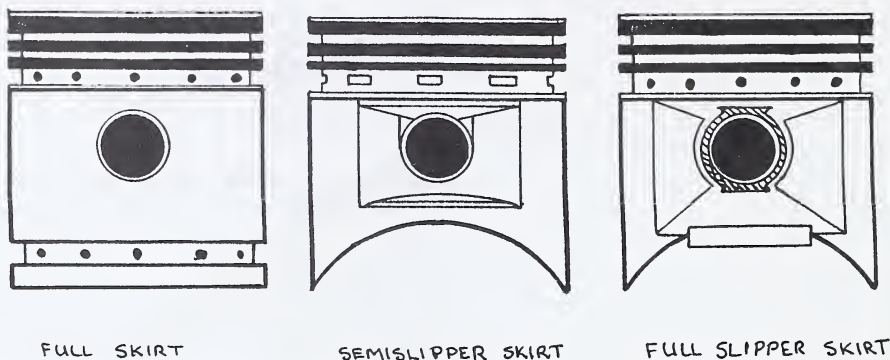
The skirt is the lower part of the piston below the oil-control ring groove. It holds the piston straight inside the cylinder.



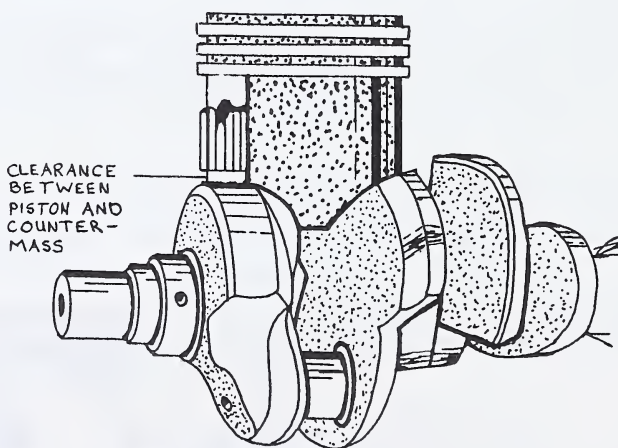
PARTS OF A PISTON

**(b) Piston Design**

The modern piston is either of the semislipper or the full slipper type.



The reason for using a slipper piston is that, on the short-stroke engine, the skirt had to be cut away to allow room for the counterweights on the crankshaft. Also, the slipper piston is shorter, making it lighter. This reduces the inertia load on the engine bearings.



Most automotive engine pistons today are made of aluminum alloys. These alloys are not only strong and light but also are a very good conductor of heat. It quickly carries excess combustion heat (which at the piston head could be higher than  $3000^{\circ}\text{C}$ ) away from the piston head and releases it to the cylinder walls and lubricating oil.

In addition to being strong, light, and heat resistant, the piston should fit reasonably tightly into the cylinder. It cannot fit too tightly in the cylinder as there must be room enough for the piston to expand with combustion heat (referred to as piston clearance).

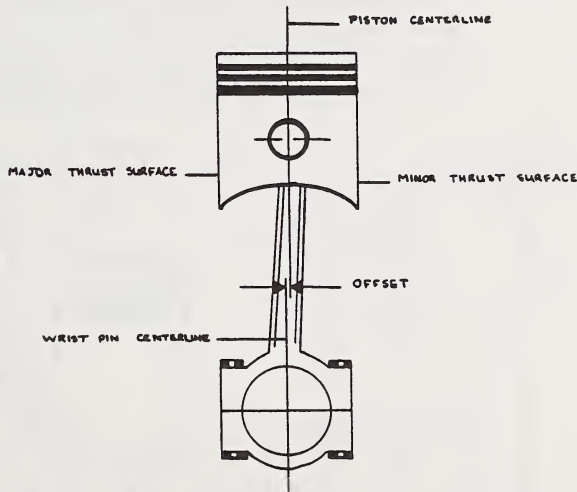
If the clearance is too small, there will be excess friction which results in loss of power, severe wear, and possible seizure of the piston and cylinder. If clearances are too large, piston slap will result. Piston slap is caused by the sudden tilting of the piston as it starts down on the power stroke.

Most pistons are made so that they have a slightly oval shape when cold. This type of piston is referred to as "cam ground." When the piston is cold, normal piston clearance exists in only a small area and has excessive clearance elsewhere. As the piston heats up it assumes a round shape due to the inconsistent expansion of the piston.

As mentioned earlier, there are many shapes of pistonheads. The simplest pistonhead is flat. However, increasing compression ratios and other engine modifications have made it necessary to reduce the clearance volume (volume above the piston at TDC). To make room for the valves to open without striking the piston, notches or hollows in the piston head are used. Some pistonheads are dished to improve the turbulence of the air-fuel mixture which in turn improves the combustion of the mixture.

### (c) Piston Markings

The piston pin (wrist pin) is offset slightly in the piston so that more compression forces will press on the major thrust surface (larger side) of the piston.



Since the wristpins are offset, it is crucial that the pistons not be reversed in the cylinders. To aid in the proper positioning of the pistons, manufacturers commonly mark the pistonhead with a notch, an arrow, or the letter "F." This marking signifies the side of the piston that is to face the front of the engine.

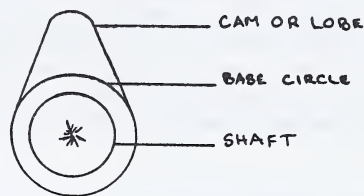
Piston size is also marked on the head of the piston. A standard size piston will usually be indicated by "std." If it is not standard size, its actual size over standard will be given either in millimeters or inches.

## VALVES AND VALVE TRAINS

We have already mentioned three types of valve train assemblies (cylinder head designs): the L-head, the I-head, and the overhead camshaft. L-head engines are found in antique cars and in small engines of the lawnmower variety. The I-head arrangement and the overhead camshaft design are common in modern automobile engines and will be covered in more detail.

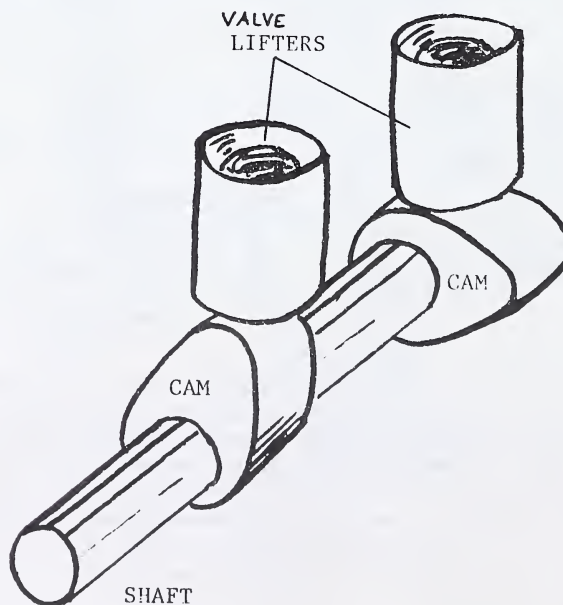
### 1. The Camshaft

The camshaft regulates the opening and the closing of the valves and also controls how long they remain open. The means by which it accomplishes this task is the cam. A cam is simply a smooth projection, offset on one side of a wheel or round shaft.

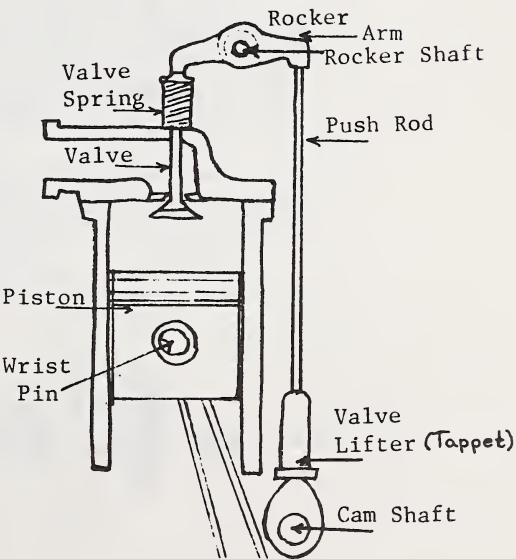
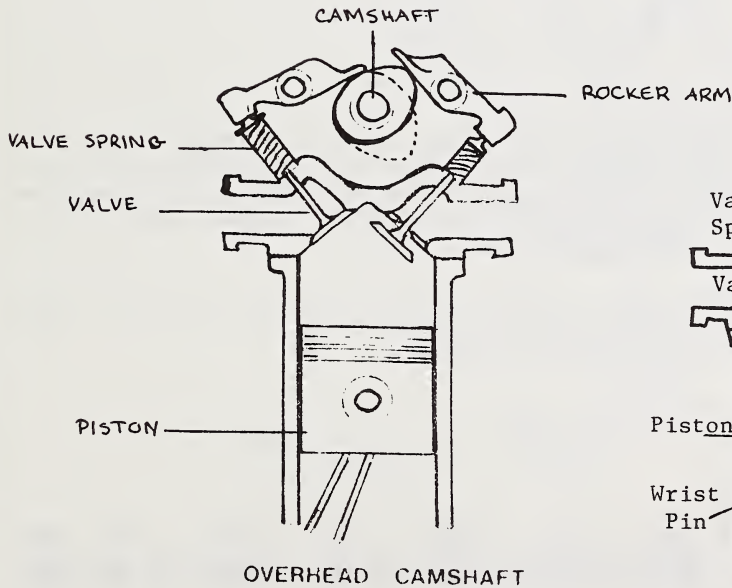
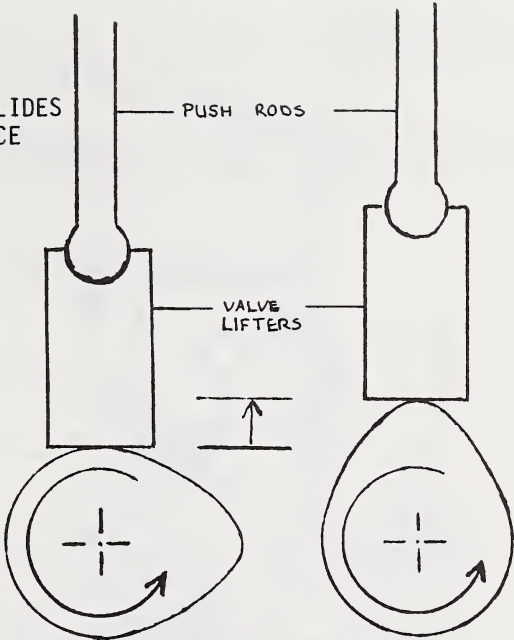


A CAM LOBE

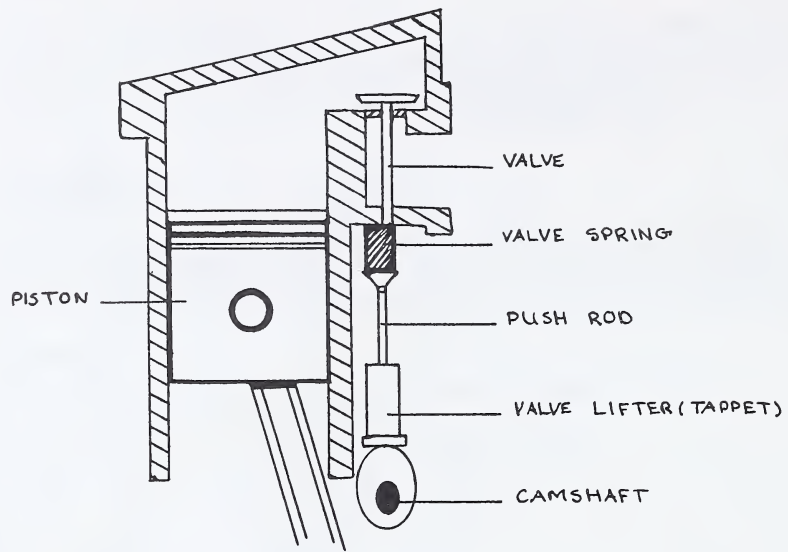
The length of the camshaft allows room for a separate cam to operate each valve. As the camshaft turns, each cam acts like a separate lever and opens its valve at the correct time. In order to open the valves at the correct time (usually referred to as valve timing) the cams are offset at different angles around the camshaft.



THE LIFTER SLIDES  
ON THE SURFACE  
OF THE CAM.



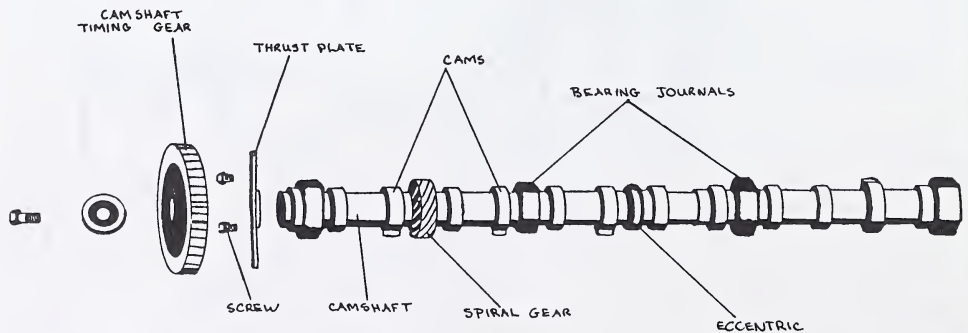
I-HEAD VALVE ASSEMBLY



L-HEAD VALVE ASSEMBLY

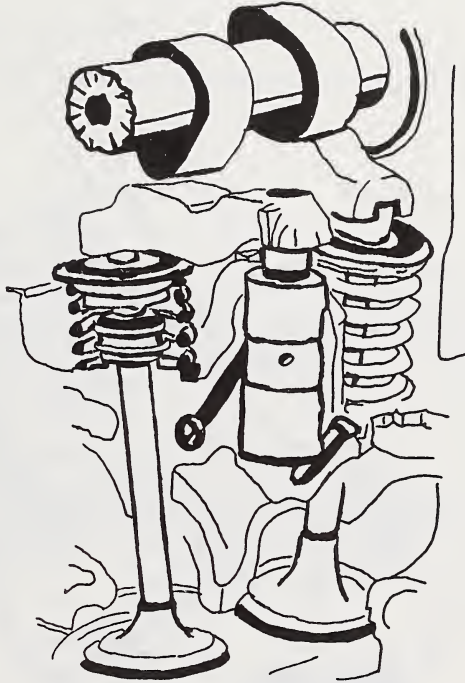
Regardless of engine construction differences, camshafts are designed to turn exactly one-half the speed of the crankshaft. This is done by driving the camshaft using gears or sprockets (timing gears) of exactly the right size. Some camshafts have a timing gear at the end that meshes directly with a gear on the accessory end of the crankshaft. Others are driven by either a chain or cogged belt (timing chain or belt).

The camshaft in many engines also has an eccentric to operate the fuel pump and a spiral gear to drive the ignition distributor and the oil pump.



In most engines, the camshaft is mounted using bearings, or bushings, in the lower part of the cylinder block. In engines with overhead camshafts (OHC), the camshaft is mounted in bearings on top of the cylinder head.

The overhead camshaft has the advantage of using fewer parts, and the parts that are used are lighter. The engine can run at higher speeds, with precise control of the valves.

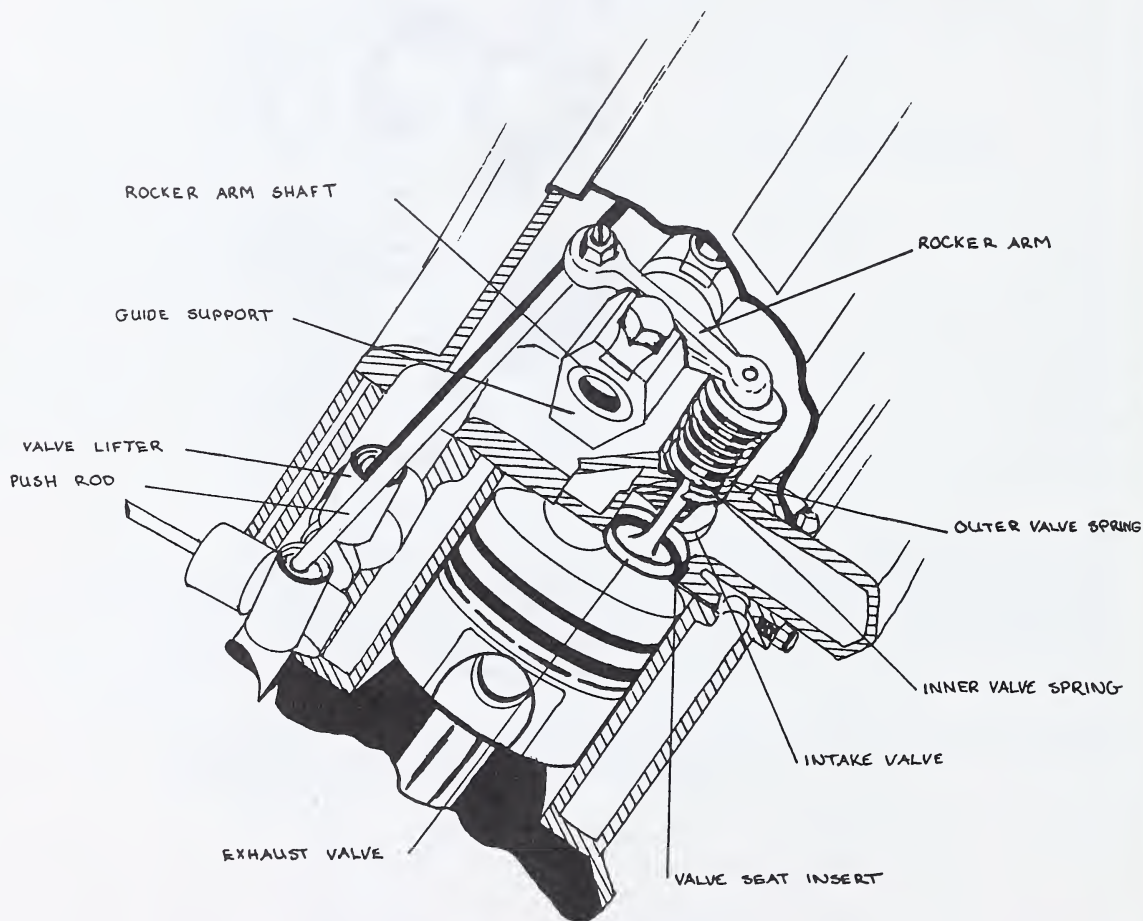


Single Overhead Camshaft Assembly (SOHC)

## 2. Rocker Arms and Push Rods

The I-head engine with overhead valves contains two other parts necessary for valve operation. They are the push rod (tappet) and the rocker arm.

The push rods rest on the valve lifters and extend through holes in the block to press against the bottom of the rocker arm. The rocker arm is a precision design seesaw. Its primary function is to turn the upward motion of the push rod into downward motion which in turn depresses the valve spring and opens the valve. Rocker arms also provide a means of adjusting valve train clearances.



CYLINDER HEAD AND VALVES

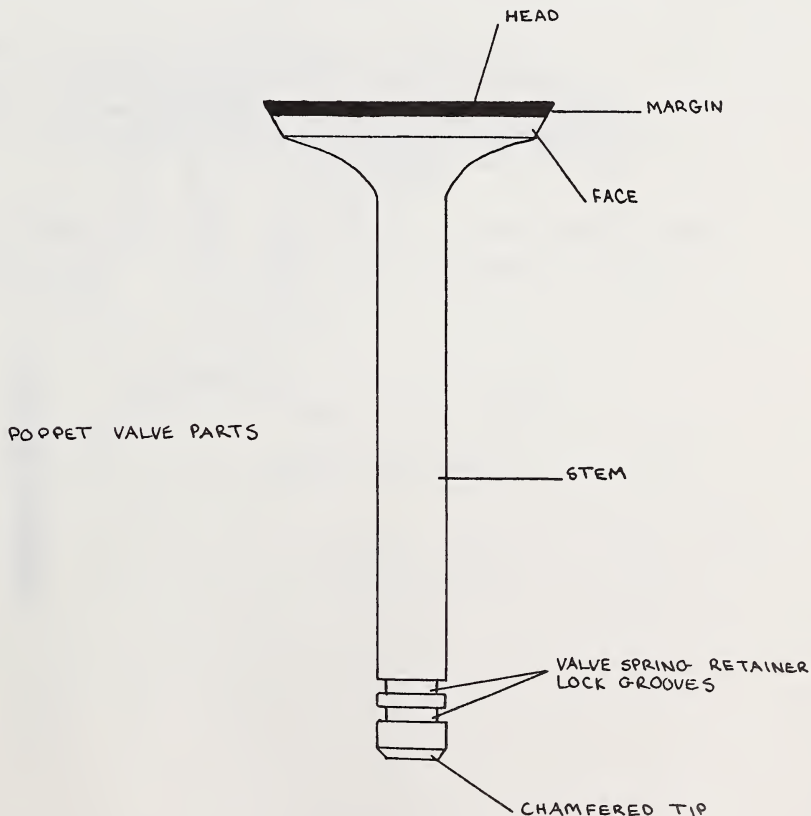
### 3. Valve Lifters

There are two types of valve lifters; the solid lifter and the hydraulic lifter. Solid lifters are used on older styles of vehicles. The solid lifter is simply a cylinder placed between the cam and the push rod. The lifters used on most modern engines are of hydraulic type. They, too, are fitted between the cam and the push rod. The hydraulic valve lifter offers many advantages:

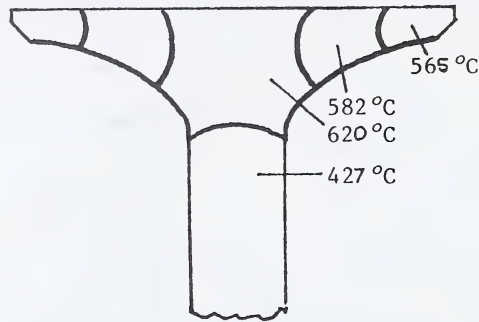
- (a) It eliminates the need for periodic valve lash adjustments. (Valve lash is the sum of all valve train clearances.)
- (b) Reduces valve train noise.
- (c) It compensates automatically to variations due to temperature changes or for normal wear.

### 4. Valves

You may have noticed that the fuel air mixture and exhaust gases are controlled by valves called poppet valves. Poppet valves are used to let the fuel mixture into the combustion chamber, seal the combustion chamber tightly, and to let the burned gases escape. Valves in an automobile engine are made of very strong alloy steel, because the valve is subjected to repeated pounding and extremely high temperature.



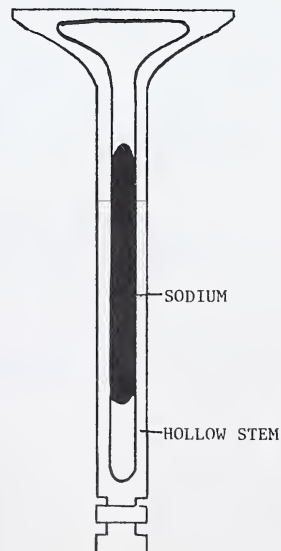
The exhaust valve in particular is exposed to very high heat. The exhaust gases rushing past the open exhaust valve heat it to such high temperatures that the exhaust valve has to be made of special steels. It not only has to withstand the high temperatures but also the corrosive effects of the exhaust gases. The valve is therefore made of cobalt chrome, silicon chrome, or nickel-chrome alloy steel. Special alloys such as manganese, silicon, and molybdenum are also used.



OPERATING TEMPERATURES IN AN EXHAUST VALVE.  
VALVE IS SHOWN IN CROSS SECTION.

In order to make the exhaust valve run cooler, some exhaust valves are made hollow. The space is then partially filled with sodium. Sodium is a soft metal which becomes liquid at 98 °C, the temperature that most engines operate at. The molten sodium runs up and down the hollow valve and transfers heat from the valve head to the cooler valve stem, the valve guide, and the engine block.

A SODIUM COOLED EXHAUST VALVE

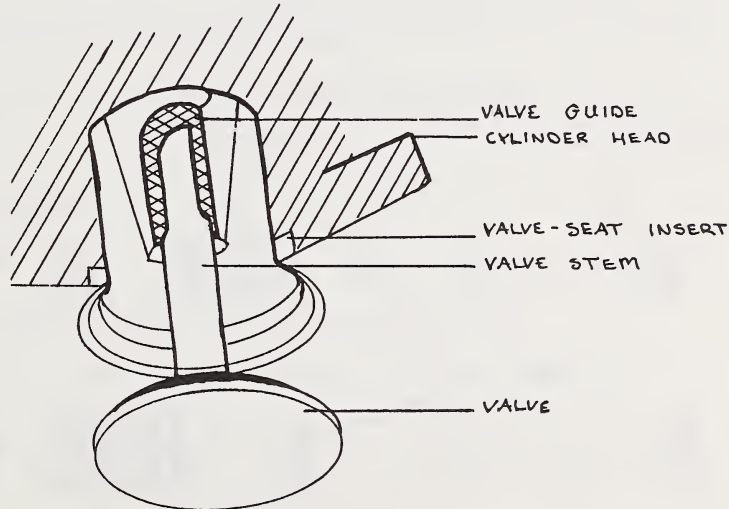


**CAUTION:** Sodium is a highly reactive substance. If a piece of sodium is dropped into water, it will explode violently into flame. It will cause deep and serious burns if it gets on your skin. Thus never cut into a sodium-cooled valve.

Exhaust valves are smaller in size than intake valves due to the pressures involved. On the intake cycle, the only thing that forces air and fuel into the cylinders is atmospheric pressure, which is approximately 100 kPa. However, on the exhaust cycle, the gases in the cylinder can be under several million pascals of pressure when the exhaust valve first opens. Due to the higher pressure, the exhaust gases can flow through a relatively small exhaust valve opening as compared to the intake mixture opening.

The valve seat is the portion of metal that the valve sits on. On very plain simple engines the cast iron of the cylinder head is sufficient for a seating for the valve. However, by inserting special metals into the area of the block where the valve sits, a valve seat that will last substantially longer will be produced. Some engines are made of aluminum which is too soft a metal to withstand the battering of the valves. A special high strength steel-alloy seat is always inserted into the aluminum.

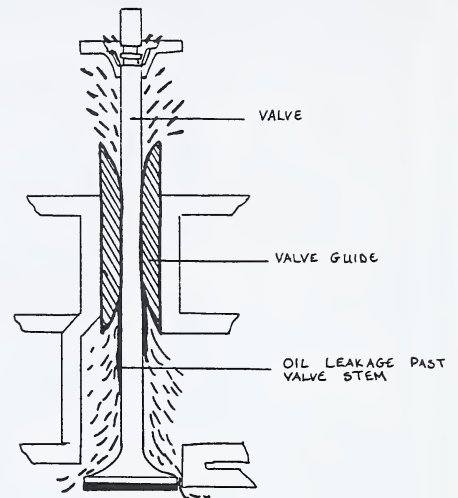
The valves run in long tubular bushings called valve guides. These are usually made of a close grained cast iron or of phosphor bronze. Phosphor bronze is the better of the two materials since it gives less wear and better heat conduction.



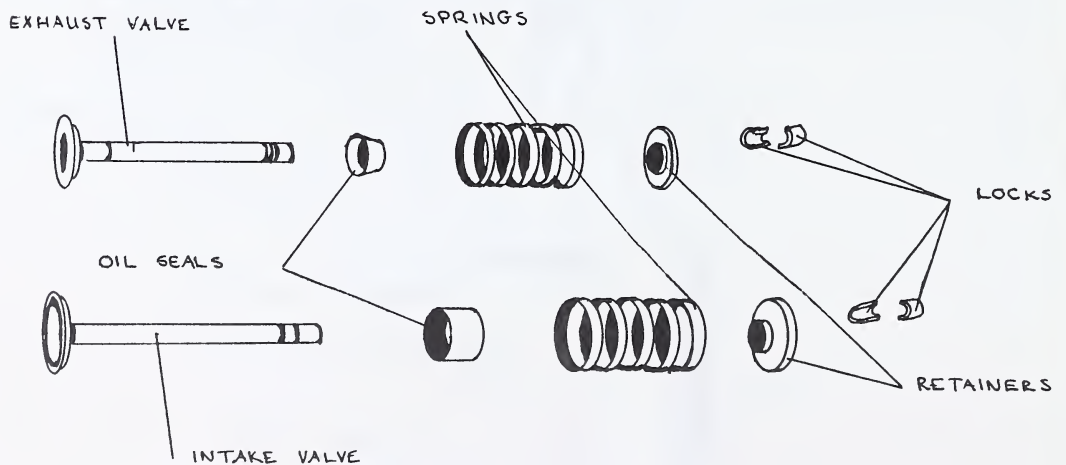
VALVE ASSEMBLY IN A CYLINDER HEAD

Since valve guides are subject to wear, they can be replaced when excessive oil consumption due to excessive valve guide clearances is diagnosed.

OIL LEAKAGE DUE TO A WORN VALVE GUIDE



A problem that exists with any overhead valve engine is preventing oil leakage between the valve stem and guide. Besides keeping stem-to-guide clearances to very fine tolerances, manufacturers install a deflector and oil seal on the stem. The deflector is usually made of metal and the seal is made of teflon.



**SELF-CORRECTING EXERCISE 1****Fill In The Blanks**

1. Cylinder blocks are made of \_\_\_\_\_ or \_\_\_\_\_.
2. The crankshaft bearings are often referred to as the \_\_\_\_\_ bearings.
3. The \_\_\_\_\_ is attached to the rear of the crankshaft.
4. The service item that includes the cylinder block, with crankshaft, pistons with piston rings, and connecting rods installed is known as the \_\_\_\_\_.
5. The camshaft regulates the \_\_\_\_\_ and the \_\_\_\_\_ of the valves.
6. The camshaft turns \_\_\_\_\_ for each turn of the crankshaft.
7. The crankpins of a V-8 engine are arranged to deliver the power pulses of a piston every \_\_\_\_\_ degrees.
8. The \_\_\_\_\_ refers to the area between the piston ring grooves.
9. \_\_\_\_\_ is caused by the sudden tilting of the piston as it starts down on the power stroke.
10. \_\_\_\_\_ valves are larger in size than the \_\_\_\_\_ valves.

**SELF-CORRECTING EXERCISE 2****Multiple Choice**

Place the letter of the best answer in the space to the left.

- \_\_\_\_\_ 1. Most connecting rods have what type of shape?
  - (a) Truss type
  - (b) Main beam
  - (c) I beam
  - (d) None of the above
  
- \_\_\_\_\_ 2. Slipper type pistons are commonly found
  - (a) in racing engines.
  - (b) in heavy duty diesel engines.
  - (c) only in older automobile engines.
  - (d) in most modern automobile engines.

- \_\_\_\_\_ 3. Which ring groove has holes drilled through to the inside of the piston?
- (a) Top compression ring groove
  - (b) Second compression ring groove
  - (c) Oil ring groove
  - (d) All three ring grooves
- \_\_\_\_\_ 4. What is the purpose of the holes mentioned in question 3?
- (a) To relieve pressure behind the ring.
  - (b) To allow oil to drain through.
  - (c) To direct pressure to the ring.
  - (d) To make the piston lighter.
- \_\_\_\_\_ 5. The L-head design is
- (a) limited to antique cars and small engines.
  - (b) used mostly in racing and other high performance engines.
  - (c) used in most modern engines.
  - (d) obsolete.
- \_\_\_\_\_ 6. Which type of valve requires special safety precautions?
- (a) Alloy steel
  - (b) Nickel chrome
  - (c) Molybdenum exhaust valves
  - (d) Sodium cooled
- \_\_\_\_\_ 7. Which type of engine design is **least** likely to use rocker arms?
- (a) I-head
  - (b) L-head
  - (c) SOHC
  - (d) Aluminum head
- \_\_\_\_\_ 8. Valves run in tubular bushings called
- (a) valve seats.
  - (b) valve stems.
  - (c) valve guides.
  - (d) valve inserts.
- \_\_\_\_\_ 9. The camshaft and crankshaft are most likely to rotate in opposite directions when the camshaft is driven by
- (a) a silent chain.
  - (b) a double link roller chain.
  - (c) a cogged belt.
  - (d) gears.

- \_\_\_\_\_ 10. Which engine is better for higher speeds?
- (a) L-head
  - (b) overhead valve
  - (c) overhead camshaft
  - (d) V-8

### SELF-CORRECTING EXERCISE 3

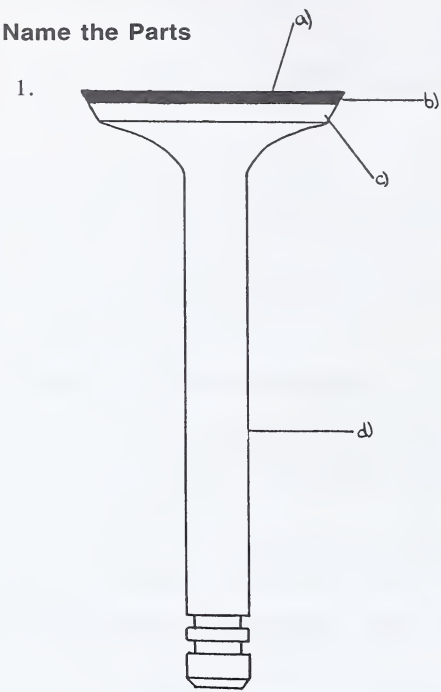
#### True or False

Write the letter T (True) or F (False) in the space to the left.

- \_\_\_\_\_ 1. Connecting rod bearing caps should not be reversed or swapped around.
- \_\_\_\_\_ 2. Wrist pins are usually hollow.
- \_\_\_\_\_ 3. Piston heads are most always flat.
- \_\_\_\_\_ 4. Camshafts contain a separate cam to operate each valve.
- \_\_\_\_\_ 5. Molybdenum rings help prevent scuffing.
- \_\_\_\_\_ 6. The big end of the connecting rod is attached to the piston with a wrist pin.
- \_\_\_\_\_ 7. Usually two compression rings are used on each piston.
- \_\_\_\_\_ 8. Solid valve lifters are more common in modern engines.
- \_\_\_\_\_ 9. The camshaft passes power and torque to the transmission.
- \_\_\_\_\_ 10. The expander ring increases ring pressure.

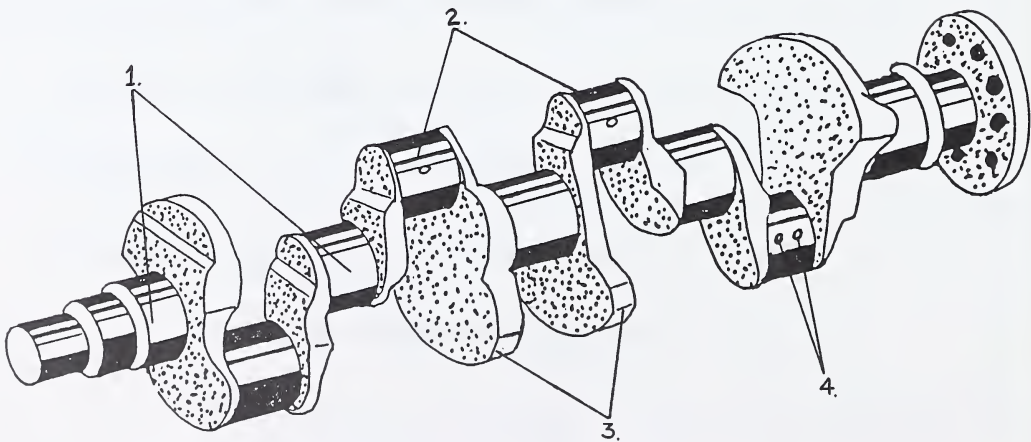
SELF-CORRECTING EXERCISE 4

Name the Parts



- (a) \_\_\_\_\_
- (b) \_\_\_\_\_
- (c) \_\_\_\_\_
- (d) \_\_\_\_\_

2. Match the numbered parts with their proper names.



- |                             |                      |
|-----------------------------|----------------------|
| _____ Main bearing journals | _____ Crank pins     |
| _____ Oil passages          | _____ Counterweights |

Send in the following exercise for correction.

**EXERCISE 1: Short Answer**

1. What three advantages do hydraulic valve lifters offer over the solid type?

(a) \_\_\_\_\_

(b) \_\_\_\_\_

(c) \_\_\_\_\_

2. What three functions does the flywheel serve?

(a) \_\_\_\_\_

(b) \_\_\_\_\_

(c) \_\_\_\_\_

3. Why is the wrist pin offset in the piston?

\_\_\_\_\_  
\_\_\_\_\_

4. What is the purpose of the crankshaft?

\_\_\_\_\_  
\_\_\_\_\_

5. The major function of the cylinder block is to provide an unmoveable mounting that keeps internal parts in exact alignment. Explain why this is necessary.

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

6. What is the function of the oil-control ring?

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7. Explain the term "piston clearance."

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8. Give two advantages of aluminum pistons.

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9. Exhaust valves are smaller in size than intake valves. Why?

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**ANSWERS TO SELF-CORRECTING EXERCISES****Self-Correcting Exercise 1**

1. cast iron; aluminum (page 2)
2. main (page 4)
3. flywheel (page 4)
4. short block (page 4)
5. opening; closing (page 18)
6. one half (page 20)
7. 90 (page 9)
8. land (page 15)
9. Piston slap (page 17)
10. Intake; exhaust (page 25)

**Self-Correcting Exercise 2**

1. c (page 10 diagram)
2. d (page 16)
3. c (page 15)
4. b (page 15)
5. a (page 6)
6. d (page 25)
7. b (pages 18 and 22)
8. c (page 25)
9. d (page 20 inferred)
10. c (page 21)

**Self-Correcting Exercise 3**

1. T (page 12)
2. T (page 10)
3. F (pages 15 and 17)
4. T (page 18)
5. T (page 13 inferred)
6. F (page 10)
7. T (page 12)
8. F (page 23)
9. F (page 9)
10. T (page 14)

**Self-Correcting Exercise 4**

- |                                   |                         |
|-----------------------------------|-------------------------|
| 1. (a) head (page 23)             | (c) face (page 23)      |
| (b) margin (page 23)              | d) stem (page 23)       |
| 2. <u>1</u> Main bearing journals | <u>4</u> Oil passages   |
| <u>2</u> Crank pins               | <u>3</u> Counterweights |

**END OF LESSON 3**

## LESSON RECORD FORM

1746 Mechanics 12  
Module 1

### FOR STUDENT USE ONLY

Date Lesson Submitted

(If label is missing  
or incorrect)

File Number

Time Spent on Lesson

Lesson Number \_\_\_\_\_

### Student's Questions and Comments

Apply Lesson Label Here

Name \_\_\_\_\_

Address \_\_\_\_\_

Postal Code \_\_\_\_\_

*Please verify that preprinted label is for  
correct course and lesson.*

### FOR SCHOOL USE ONLY

Assigned  
Teacher: \_\_\_\_\_

Lesson Grading: \_\_\_\_\_

Additional Grading  
E/R/P Code: \_\_\_\_\_

Mark: \_\_\_\_\_

Graded by: \_\_\_\_\_

Assignment Code: \_\_\_\_\_

Date Lesson Received:

Lesson Recorded \_\_\_\_\_

Teacher's Comments:

\_\_\_\_\_  
Correspondence Teacher

## **ALBERTA DISTANCE LEARNING CENTRE**

### **MAILING INSTRUCTIONS FOR CORRESPONDENCE LESSONS**

#### **1. BEFORE MAILING YOUR LESSONS, PLEASE SEE THAT:**

- (1) All pages are numbered and in order, and no paper clips or staples are used.
- (2) All exercises are completed. If not, explain why.
- (3) Your work has been re-read to ensure accuracy in spelling and lesson details.
- (4) The Lesson Record Form is filled out and the correct lesson label is attached.
- (5) This mailing sheet is placed on the lesson.

#### **2. POSTAGE REGULATIONS**

Do not enclose letters with lessons.

Send all letters in a separate envelope.

#### **3. POSTAGE RATES**

First Class

Take your lesson to the Post Office and have it weighed. Attach sufficient postage and a green first-class sticker to the front of the envelope, and seal the envelope. Correspondence lessons will travel faster if first-class postage is used.

Try to mail each lesson as soon as it has been completed.

When you register for correspondence courses, you are expected to send lessons for correction regularly. Avoid sending more than two or three lessons in one subject at the same time.

## **SAFETY**

Introduction  
Causes of Accidents  
Accident Prevention  
General Safety and First Aid  
Safe Operation of Tools and Equipment  
Worker's Compensation

### **INTRODUCTION**

Developing safe work habits is one of the most important aspects of mechanics. It does little good to attempt to repair your own vehicle if while doing so you seriously injure yourself.

In general an accident is an unplanned and unexpected event which interferes with the activity a person is engaged in. An accident can happen to the worker himself or it may lead to the injury of other workers.

The result of an accident to an individual can range from minor irritation to major injury or disaster. An accident can cause no damage to equipment or total destruction could result.

When an accident occurs, one can never be sure of the outcome. This is the reason why a person has to strive to prevent accidents.

### **CAUSES OF ACCIDENTS**

Accidents do not just happen. For example, a person can easily cause an accident by repairing electrical equipment while it is still hooked up to power. The question to ask of this type of person is not whether an accident will happen, but when the accident will occur, since sooner or later the worker will accidentally touch a live wire.

This type of worker would not be truthful in saying "Look, an accident happened to me." He should say "Look, I just caused an injury to happen to me."

***ACCIDENTS ARE CAUSED. HELP REMOVE CAUSES.***

Below are some of the more common causes of accidents.

**1. Unsafe Acts**

**An unsafe act is any departure by the worker from an accepted, normal, or correct procedure or practice. Unsafe acts lead to accidents.**

Below is a list of many acts which are considered unsafe. The list is by no means complete but it should give a good idea of what an unsafe act is.

- (a) Activities such as operating equipment unexpectedly without warning people in the vicinity, operating equipment before checking out its condition with a supervisor and receiving permission, and operating equipment before securing accessories, all constitute unsafe acts. Below are some specific examples.
  - (i) Starting or suddenly moving equipment without authority or without letting other workers know your intention leaves these workers unaware of what is happening (startles them) and this increases the chance of an accident occurring. Sudden unexpected stopping of equipment can also cause an accident.
  - (ii) Failure to secure is another cause of accidents. Failing to secure can mean failure to lock brakes or block vehicles against unexpected motion. This is especially important when working under a vehicle. Failure to secure can also apply to locking a switch in the off position so another worker will not accidentally turn the switch on and cause an accident. An electrician can easily be electrocuted because another worker did not notice him working on a piece of equipment before he turned on the electrical breaker. The electrician should label the breaker box with a warning sign indicating the equipment is being serviced and then lock the breaker in the off position.
  - (iii) Failure to shut off equipment when not in use can lead to people accidentally touching moving equipment or hot equipment (such as a soldering iron).
  - (iv) Also the worker is performing an extremely unsafe act if he enters a tank or vessel without checking to ensure there is adequate oxygen and no poisonous gases inside.
  - (v) Lifting with a bent back is an unsafe act which could lead to serious back injury.

- (b) Another unsafe act is operating equipment at unsafe speeds or working at unsafe speeds. Examples are listed below.
  - (i) Running on a job site is never considered safe. There are endless obstacles to run into especially if one were to slip and fall.
  - (ii) Walking backwards is a very unsafe act.
  - (iii) Working too fast or too slow and thus endangering others is unsafe.
- (c) Making safety devices inoperative is extremely hazardous. Remember they are there for a reason. Why are they installed on machines? — For the protection of the worker so he will not get caught in the machine or cut by it or hit by flying parts, etc. Below is a list of things to observe.
  - (i) Do not remove or disconnect safety devices such as belt guards on air compressors.
  - (ii) Do not block, plug, or tie safety devices so they do not function.
  - (iii) Do not replace safety devices with those of improper capacity. For example, do not use higher amperage electrical fuses than those recommended.
- (d) Another extremely hazardous act involves using equipment which is unsafe. Some examples and the hazards they present are listed below.
  - (i) Using defective equipment such as cold chisels with mushroomed heads is unsafe. Metal chips can break off these heads and injure or blind the operator or an observer.
  - (ii) Gripping objects insecurely or incorrectly is not a safe practice. A hammer, for example, can very easily slip out of your hand if you do not grip it firmly. A flying hammer is extremely dangerous to other workers.
- (e) Unsafe procedures involving loading, piling, or mixing supplies can be an extremely dangerous act. Examples are listed below.
  - (i) Overloading a machine (a hoist for example) may cause a lift cable to break and the load to fall.
  - (ii) Incorrect mixing can cause serious explosions, fires, and burns. For example, pouring water into acid is wrong. If done, it can cause serious heat and acid burns as the solution boils violently when the water is added.
- (f) A worker must always be observant about his location or posture.
  - (i) A worker who moves under a suspended load is performing an unsafe act.

- (ii) Also the worker is performing an extremely unsafe act if he enters a tank or vessel without checking to ensure there is adequate oxygen and no poisonous gases inside. Likewise, it is extremely unsafe to run a vehicle engine with all garage doors closed, unless a fan is carrying the exhaust fumes out.  
**Remember - Carbon monoxide is a tasteless, odorless but extremely deadly gas.**
- (iii) Lifting with a bent back is an unsafe act which could lead to serious back injury.
- (g) Working on or around moving or dangerous equipment can lead to many unsafe acts. Some unsafe acts are:
  - (i) Getting on or off moving equipment (vehicles, conveyors, elevators).
  - (ii) Cleaning, oiling, and adjusting moving machinery. Always stop a machine before adjusting and servicing. You could easily get caught and pulled into a machine.
  - (iii) Working on electrical equipment without disconnecting the power source.
  - (iv) Welding or cutting on dangerous materials. (Many gasoline drums have exploded when a person has tried to remove the top with a cutting torch. Fumes will remain in these drums for years.)
- (h) Distracting, teasing, abusing, or startling, etc. are all unsafe acts.
  - (i) Any distraction can lead to the worker's attention being diverted from his job and as a result he could get caught in a machine or cut. Startling a worker could lead to the same result.
  - (ii) Throwing material distracts or injures workers and hence is an unsafe act.
  - (iii) Practical joking is also an unsafe act.
- (i) Failure to use safe attire is also considered an unsafe act. Examples of unsafe acts related to this are:
  - (i) failure to wear eye protection, gloves, masks, aprons, or proper shoes.
  - (ii) wearing long sleeves, loose clothing, ties, etc.
  - (iii) failure to report any safety apparel that is defective.

Keep in mind that what might be considered a safe act in one type of work may not be safe for other types of work. A good example of this concerns the use of gloves. Gloves are a necessity for a person working with hot metals but gloves may cause serious injury to someone working around moving parts as the gloves may get caught and pull the operator into the machine.

## 2. Unsafe Conditions

**An unsafe condition is any hazardous physical condition which if left uncorrected may lead to an accident.**

Below is a list of the types of conditions which are considered unsafe.

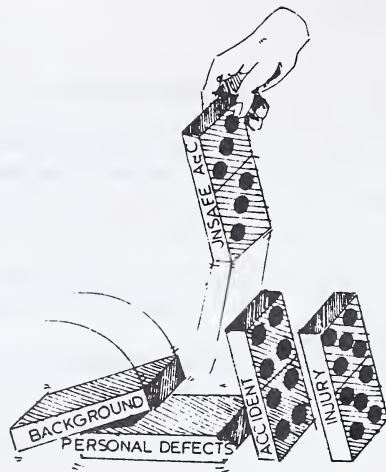
- (a) Improperly guarded, incorrectly guarded, or unguarded machines are considered unsafe as they expose the worker to moving parts or hazards from flying materials.
- (b) Defective equipment would also provide unsafe working conditions. Machines which are aged, worn, or have cracked parts are unsafe.
- (c) Hazardous procedures or arrangements present the worker with unsafe conditions. Some of these unsafe conditions are:
  - (i) improperly stored or piled materials and incorrectly stored tools.
  - (ii) congested work areas or inadequate aisle space.
  - (iii) oil, water, grease, or paints on a working surface.
  - (iv) floors which are slippery.
- (d) Improper lighting is another unsafe working condition. Insufficient or no light makes it harder to recognize hazardous conditions. Glare could result in the same thing. Excess light such as from welding could lead to eye damage and hence this presents an unsafe working condition.
- (e) Improper ventilation in the work area which results in excess dust, fumes, or temperature can be hazardous to the workers' health. Some fumes can in fact be fatal if not removed immediately.
- (f) Unsafely designed or constructed equipment can mean unsafe working conditions. Scaffolding which is improperly constructed can be fatal to a worker on them if the structure collapses.

The National Safety Council released the following statement concerning causes of accidents:

Unsafe acts causes	88% of all accidents
Unsafe conditions cause	10% of all accidents
Acts of God cause	2% of all accidents

**HELP PREVENT  
ACCIDENTS**

# ELIMINATE THE UNSAFE ACTS AND CONDITIONS



## ACCIDENT PREVENTION

Accidents can be prevented by removing the unsafe acts and conditions. This, however, is easier said than done. Before these unsafe acts and conditions can be removed, they must be recognized. The greater a person's ability to recognize a dangerous act, the less accident prone he tends to be.

### 1. Know Your Tools

The more that a person knows and understands about a tool, the less likely he will be to have an accident with that tool. Below are some suggestions for recognizing where accidents may occur.

- (a) Cutting tools are designed to cut away materials. If a worker is positioned so he is ahead of a cutting tool, any slip will cause an accident. A good example of this is a gasket scraper. Any slip of the scraper when the worker has a hand in front of it could lead to a cut. However, a less recognized but more dangerous act occurs while pushing a board into a table saw. If the person positions a hand in front of the blade and pushes the board towards the blade, any slip could result in the loss of his fingers or entire hand.

Knowledge of safety should be transferred from one situation to another. The previous examples point this out quite well.

- (b) All tools and machines have correct operating procedures. Do not use the tools or machines until you are familiar with these procedures. It is possible to gain this knowledge from books on machine operation or from a good demonstration by a knowledgeable person. Do not attempt to operate a machine until you know how to do the procedures correctly and know why they are done that way.
- (c) Tools and machines have limitations. They will only do the jobs they were designed for. Carefully read the instruction booklet to determine which jobs can be done. Also check for suggestions on operating procedures and warnings.
- (d) Check for bulletins published by the equipment manufacturer concerning updating older equipment. Also check for hazards which may have been discovered in newer equipment.

## 2. Know Yourself

Every person has limitations, both physical and mental. For example, do not attempt to do jobs for which you are not strong enough to handle. If material is removed from a shelf but cannot be held because it is too heavy, an accident could easily result.

Close calls should be a warning that proper procedures are not being followed.

## GENERAL SAFETY AND FIRST AID

Below is a list of common accident causes and methods of prevention.

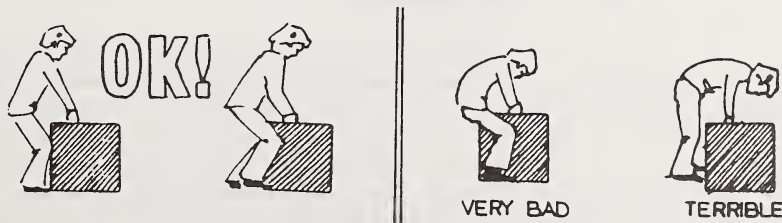
### 1. Goggles

Although most parts of our anatomy are designed to be of some use to us, possibly none is more important and none more vulnerable than the eyes. Be sensible. If there is any remote possibility that your eyes may be in danger, wear hard safety goggles. If you cut your hands it may be painful but they will heal. Cut or burn your eyes badly and you're blind for life. Below is a list of some of the work situations which require eye protection.

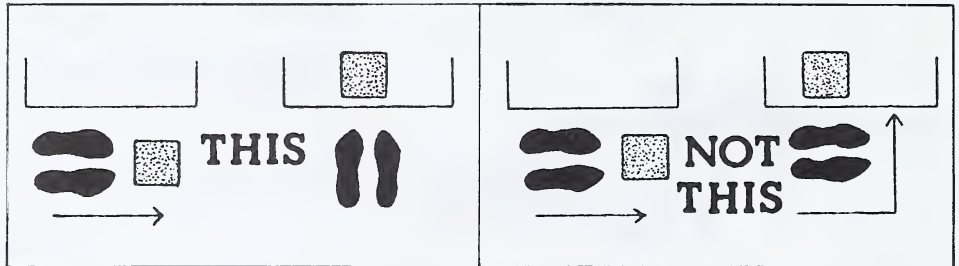
- (a) Doing hand work with a hammer and cold chisel (either yourself or someone near you),
- (b) Working near a welder,
- (c) Using a grinder (portable or stationary),
- (d) Using a skilsaw, table saw, radial saw, sander, etc.
- (e) Working under a machine or automobile, where dust or dirt may fall into your eyes.
- (f) Riding a motorbike or snowmobile.
- (g) Anywhere that an object may be thrown or may fall into your eyes.
- (h) When working on batteries.

### 2. Lifting

Lifting with a flat back is a commonly ignored rule with the result that there are a large number of people with 'back trouble.' Chiropractors and weight lifters will tell you lift with your legs. If a weight is too heavy to lift in this manner get some help or use a crane. Your back is quite strong and difficult to injure if it is straight (flat), but easily injured if bent.



There is another 'back injury' movement that should be mentioned at the same time. Do not lift and then twist at the waist to set down a weight. Many people, especially when lifting material onto a counter or truck, will lift the weight correctly and then, instead of moving their feet toward the counter, will merely swing their upper body at right angles (90°) to the hips.



People have hurt their backs doing this with no weight, but weight certainly increases the possibility of injury if handled in this manner.

### 3. Fire Safety

When constructing or repairing equipment, either at home or at work, a danger of fire caused by sparks, heat, or faulty materials is always present.

Commonly occurring fires are divided into three classes. These classes are listed below along with the fire extinguishers commonly used to control or extinguish them.

- (a) Class "A" fires occur in wood, paper, rags, etc. In these fires there are burning coals present. If only the flames are extinguished **the fire can easily re-ignite**. Many class "A" fire extinguishers are loaded with a water solution. Antifreeze is sometimes mixed with water to prevent freezing. These extinguishers are usually operated by a hand pump which discharges the water in a solid stream or a spray pattern.
- (b) Class "B" fires occur in flammable liquids such as gasoline, oil, etc. Separate fire extinguishers for Class "B" and Class "C" fires are not usually available. Fire extinguishers usually are approved for Class "B" and Class "C" fires. These extinguishers contain carbon dioxide or a dry chemical (dry powder) under pressure. When you press the discharge lever, the pressure forces the dry powder or carbon dioxide out in a fine cloud.

**NOTE:** Water should never be used on Class "B" fires as gasoline floats on water and the fire will not be extinguished. It will be spread over a larger area.

- (c) Class "C" fires occur in electrical equipment. A Class "A" fire extinguisher used in an electrical fire would cause a serious hazard because water conducts electricity. Dry chemical or carbon dioxide extinguishers rated for Class "B" and "C" fires can be used. With Class "C" fires, always turn the current off to the equipment as quickly as possible.

If a fire occurs in a shop where you are working, take care to use the proper equipment. Using the wrong extinguisher could create a more serious problem than if none had been used. Above all else, call your fire department before attempting to put out the fire. If you do not call them early you may never have the opportunity to do so later.

When using a fire extinguisher always aim it at the base of the flames.

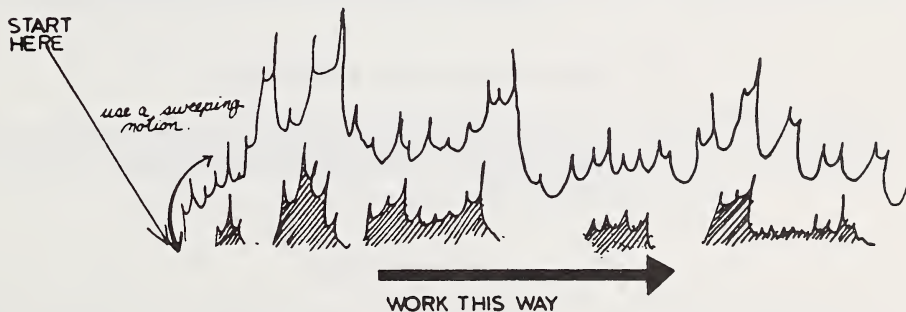
**NOT LIKE THIS**



**LIKE THIS**



This will allow you to confine the fire to a small area. Always work from the point closest to you, using a sweeping motion.



If the fire is too much for you to handle leave the area, making sure all doors are closed behind you. This will stop the fire from spreading by limiting the amount of oxygen present.

Remember your personal safety is worth much more than anything else. You can buy back tools and other equipment but not your eyes, arms or your life.

In summary there are five steps to follow.

- (a) Tell everyone in the area of the fire.
- (b) Call the fire department.
- (c) Make sure everyone is out of the danger area.
- (d) Attempt to control the fire. Do not place yourself in danger.
- (e) Leave, closing all doors behind you.

Fire extinguishers come in many price ranges and designs. Please choose a good one since many cheap units fail to operate properly at the time required. A good extinguisher will last until such time as it is needed. Also have your fire extinguisher checked regularly to see if it still has its charge.

#### 4. Cutting Tools

As cutting edges on tools were designed to quickly remove material, they can easily cut the operator. It is best to show proper respect for these cutting edges. Below is a list of do's and don'ts concerning cutting edges.

- (a) When removing gaskets keep both hands on the scraper. **Never** put your hand out in front of the work where it may be gouged by the scraper if it slips.
- (b) Never hurry or rush around power machines and always use the proper feed mechanism and push blocks (if a mistake does occur at least it's only the push block that gets chopped to ribbons).
- (c) When using portable power tools (e.g. - drill) use a vise so that you are not tempted to put your hand under the material to hold it.
- (d) Never reach around moving parts of machines (table saw, car, combine, grinder) to remove or check something. Stop the machine and then check.

#### 5. When Necessary Wear a Dust Mask

If you are working at or near a machine which shapes brake linings to fit drums, wear a dust mask. **Brake linings contain asbestos which is extremely dangerous if breathed in.**

#### 6. Keeping Work Areas Clean

A clean work area is a safer work area. If you slip on a socket laying on the floor, it is possible to be seriously injured. Similarly grease and oil on a floor can result in injury.

## 7. First Aid

### (a) Shock

Accident victims sometimes go into shock. Shock is a condition of severe depression of the vital processes of the body. Loss of whole blood or plasma from the circulation system is the most important cause of shock. The severity of shock depends upon the amount and rapidity of the bleeding. To begin with, the circulatory system may be able to adapt itself to the loss of blood and continue to function more or less adequately, but the condition of the casualty will become more critical as time passes unless the bleeding is stopped and the blood volume restored by transfusion. (Remember, not all bleeding can be readily recognized e.g. internal bleeding of abdominal cavity.)

The condition of shock may develop at once or its onset may be delayed. It is important to remember that this delay may occur, because the absence of signs and symptoms of shock may give rise to a false sense of security, or lead to an underestimation of the effects of the injury or injuries the casualty has sustained. Shock is a common cause of death following severe injuries.

The general signs of shock are pallor, cold clammy skin, nausea, giddiness, and faintness. As shock becomes more serious, a pulse which was slow at first may become progressively more feeble and rapid, coldness and greyness of skin may increase, vomiting may occur, breathing problems may be encountered, and finally, unconsciousness may result.

General shock symptoms may also result from entirely nervous factors. A fall in blood pressure, not associated with any reduction in the volume of circulating blood, may be caused by very bad news, witnessing a severe accident, etc.

A person suffering from shock will require assistance. The following steps should be taken.

- (i) Reassure the casualty.
- (ii) Lay him on his back with the head low and turned to one side unless there is an injury to the head, abdomen or chest when the head and shoulders should be slightly raised and supported. If he has vomited or if there is interference with breathing place him in the three-quarter prone position.



**Three-quarter Prone Position**

Note that a person who has assumed this position is lying on his side with his upper arm and leg bent and resting on the ground surface for body support.

- (iii) Loosen clothing about the neck, chest and waist.
- (iv) Wrap him in a blanket or rug.
- (v) If he complains of thirst he may be given sips of water, tea, coffee or other liquid but not alcohol.
- (vi) Do not apply heat or friction to the limbs. Hot water bottles should not be used.

In severe cases of shock proceed as already described but bear in mind that transfusion and surgery are matters of grave urgency if a life is to be saved. It is therefore unwise to delay transfer to hospital for as long as even five minutes except to deal with failing respiration, to stop severe bleeding, to dress a sucking wound of the chest or to secure a limb badly broken.

- (vii) Do not give anything by mouth (the casualty may require an anaesthetic and food is never allowed before an anaesthetic is used.)
- (viii) Tilt the stretcher so that the level of the head is lower than the rest of the body, except in cases of head, chest or abdominal cavity.
- (ix) Remove urgently to hospital.

#### (b) Minor Burns

In cases of **minor** burns and scalds, where the skin is not broken, immersion of the affected part in cold water will often result in great relief from pain. Bearing in mind the danger of infection, careful washing in soap and water is excellent therapy.

The cold water immersion treatment may be continued for as long as the patient feels need of the relief afforded.

Where immersion is not possible, towels or cloths soaked in clean cool water and changed frequently, may be applied to the affected area.

It may be necessary to add ice cubes to the water in the container since bodily heat will otherwise warm the water. It is not advisable to place a sensitive burn under a running faucet or shower as the pressure from the stream of water may offset the relief gained by the cool water.

During treatment, the patient should be kept as comfortable as possible. Hot drinks and blankets should be used to offset any feeling of chill. Many cases of minor burns will require no further treatment once the pain has disappeared.

**(c) Major Burns**

- (i) Use clean hands. Avoid unnecessary handling.
- (ii) Do **not** attempt to apply salves or lotions.
- (iii) Do **not** remove burned clothing if stuck to skin or if difficult to remove.
- (iv) Do **not** break blisters.
- (v) Cover the area (including burned clothing) with a dry sterile dressing if possible or other available laundered linen.
- (vi) Bandage firmly except when blisters are present or suspected, in which case bandage lightly but securely.
- (vii) Immobilize affected area by suitable means.
- (viii) Do everything possible to prevent shock - conserve body heat.
- (ix) Remove patient to hospital as soon as possible.
- (x) If medical aid is near, speed is more essential than detailed bandaging.
- (xi) In serious cases anaesthesia may be required and nothing should be allowed the patient by mouth.
- (xii) Where medical aid will be delayed for at least four hours, small drinks of water may be given the patient periodically.

In both minor and major burn cases, large amounts of water taken at one time can easily induce vomiting and, for this reason drinking where permissible, should be controlled.

**(d) Chemical Burns**

With chemical burns, speed is essential to prevent further damage.

If the corrosive chemical is an acid, proceed as follows:

- (i) Thoroughly flood the part with water.
- (ii) Bathe the part freely with an alkaline solution, such as two teaspoons (one dessert spoon) of baking soda (bicarbonate of soda) or washing soda (carbonate of soda), in one pint of warm water.
- (iii) Apply the general rules for the treatment of burns but remove contaminated clothing as quickly as possible to prevent further injury. Take reasonable precautions against burning yourself with contaminated clothing.

If the burn is the result of an alkali (or basic solution) proceed as follows:

- (i) If the burn is caused by quicklime, brush off any that remains on the part.
- (ii) Thoroughly flood the part with water.
- (iii) Bathe the part freely with a weak acid solution, such as vinegar or lemon juice, diluted with an equal quantity of warm water.
- (iv) Apply the general rules for treatment of burns, but remove any contaminated clothing immediately taking reasonable precautions.

We would like to thank the Order of St. John for supplying the above information. If at all possible we suggest that you take the St. John First Aid Course.

#### **(e) Bleeding and Bandaging**

Since bleeding is the most important cause of shock, it is important to know how to stop bleeding effectively.

The most effective method of controlling external bleeding is by direct pressure on the wound, using a sterile dressing if possible. Do not disturb the dressing as a bandage is applied, to continue the pressure. Check to make sure the bandage is not too tight and cutting off circulation. Elevate the limb above heart level except where there is a possible broken bone. Treat for shock. If blood soaks through the dressing, do not remove it, but apply more dressings.

Special signs which may indicate internal bleeding are severe thirst, apprehensiveness and restlessness (excitability) of the casualty, and very distressed efforts to breathe (the casualty may throw his arms about, tug at clothing, and call for air). This condition is extremely serious. The casualty should be removed to hospital at the earliest possible moment. A note should be attached to the victim stating that internal hemorrhage is suspected. Nothing should be given by mouth.

### **8. Warning Labels**

Regulations that require new warning labels on poisonous, flammable, explosive and corrosive products sold for everyday household use have been announced by the Canadian government.

A uniform set of symbols will show both the type and seriousness of hazard, and warning statements as well as basic first-aid information will appear on the labels in both English and French.

The label regulations are the first issued under Canada's Hazardous Products Act. They deal specifically with consumer chemical products such as bleaches, polishes, sanitizers, glues and cleaners. Each symbol is placed inside an outline that shows the degree of severity of the hazard. An octagon means "Danger," a diamond means "Warning" and a triangle means "Caution."

Some products will have to carry two or more symbols. Furniture polish in an aerosol spray can, for example, must display the symbols for "Poison/Danger," "Flammable/Warning," and "Explosive/Caution."

HAZARDOUS PRODUCT SYMBOLS			
			
DANGER POISON	DANGER FLAMMABLE	DANGER EXPLOSIVE	DANGER CORROSIVE
			
WARNING POISON	WARNING FLAMMABLE	WARNING EXPLOSIVE	WARNING CORROSIVE
			
CAUTION POISON	CAUTION FLAMMABLE	CAUTION EXPLOSIVE	CAUTION CORROSIVE

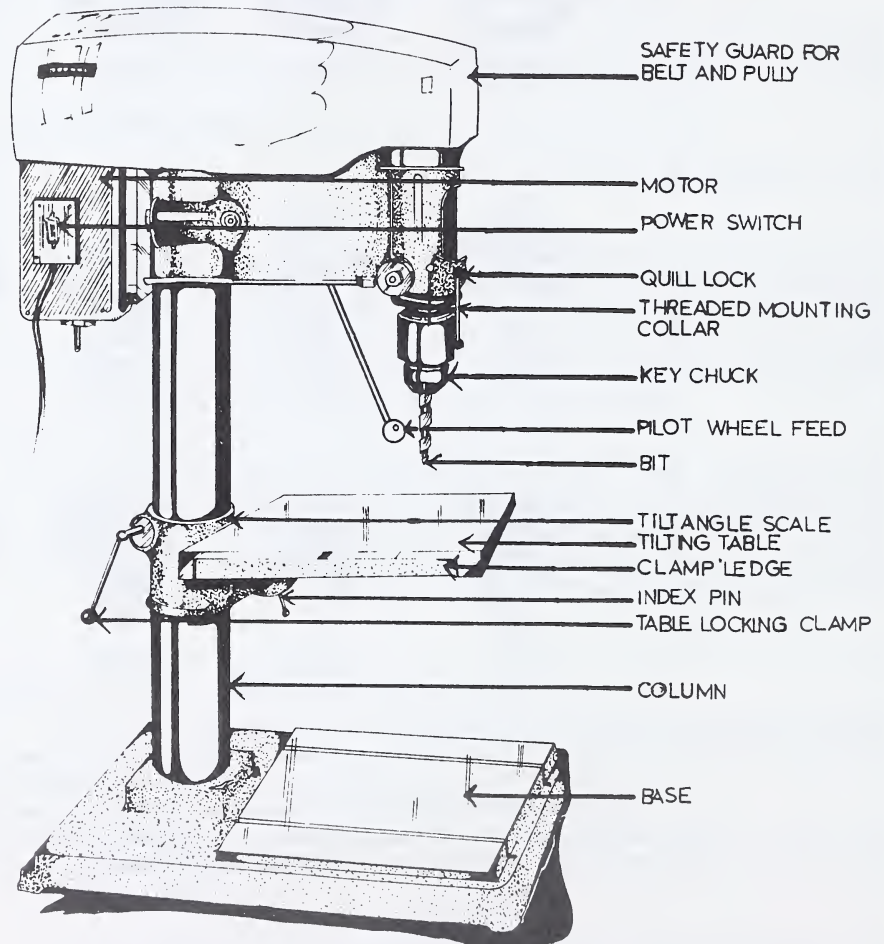
It is a good idea to always respect the warning labels on solvents, oils, and other chemicals. Many chemicals can cause medical problems if you are in contact with them often. Newer oil cans have a special warning indicating that prolonged contact with used oil has been shown to cause cancer in laboratory animals.

## SAFE OPERATION OF TOOLS AND EQUIPMENT

A mechanic must learn to safely use various types of power tools, hand tools, lifting equipment and support equipment. By being skilful in the application of tools and equipment, the mechanic will be able to do repair work faster and safer without sacrificing quality.

### 1. Power Equipment

#### (a) Drill Press



The drill press is a machine used for making holes in wood, plastic and metal. It is useful for drilling out broken studs, refilling holes in material which has been welded together, etc. The drill press is better than portable drills for several reasons.

- (i) With a drill press the feed pressure is always straight down on the drill whereas with a portable drill, the handle is offset to one side and feed pressure can be at an angle. This leads to bit breakage.
- (ii) The drill press head is always perpendicular to the drill press table. This makes drilling straight holes easier than with the portable drill.
- (iii) Drill press speeds are adjustable to insure the drill bits are turned at the proper speed.
- (iv) It is easier to apply the proper feed pressure on a drill press than on a portable electric drill. The drill press has a feed lever which increases the leverage when applying pressure on the bit.

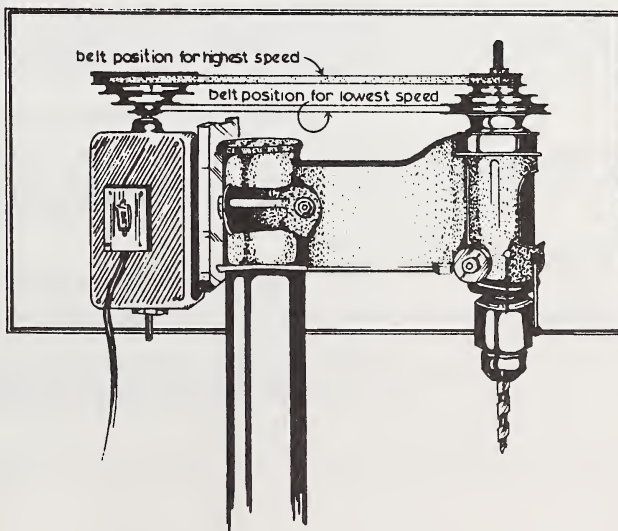
Drill presses are adjustable for the speed that they turn the bit. This is necessary because of the variety of bit diameters used. The drill speed is the distance the drill would travel in one minute if it were rolled on its side. A small drill must be rotated much faster than a large drill in order to be cutting at the same drilling speed.

### Example

The suggested drill speed for making a hole in mild steel is 30.5 metres per minute. To get this drill speed means a 3.2 mm diameter drill should turn at 3057 r/min. A 25.4 mm drill should turn 382 r/min to attain this same drill speed.

Drill speed is different for different types of bits (or drills) and for different materials. The instruction or owner's booklet for each drill press should give the required drill speeds. Textbooks are another source of drill speed information.

A drill press is adjustable for speed through the use of a step pulley on the motor and another step pulley on the drill press spindle shaft (which attaches to the chuck).



Below is a list of procedures to follow when using a drill press.

- (i) Select the correct bit. Drill presses use only round and hexagonal shanked bits. Do not attempt to use square tanged bits in a drill press chuck.
- (ii) Ensure that the speed is set correctly for the type and size of bit used.
- (iii) Set the depth stop if the hole is not to be drilled all the way through the material. The depth stop will only allow the drill to move downward to the depth it was set at.
- (iv) Use a vise or clamp to properly secure smaller material. A hand can easily be cut if the drill grabs small material such as a piece of sheet metal and rotates it through your fingers.
- (v) Align the drill with the hole in the table when drilling in metal. This is done to keep the drill from ruining the drill press table as the drill comes through the work.

#### **(b) Portable Electric Drills**

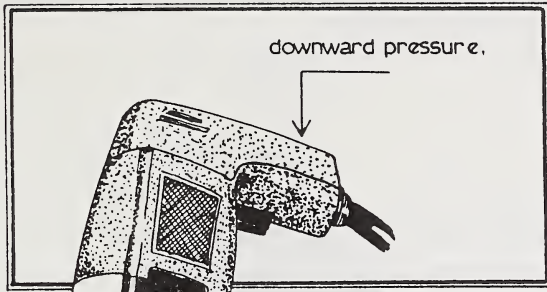
A portable electric drill will never replace a drill press for quality of holes, or ease of making holes in small work. The portable drill, however, allows for much more portability. A drill press cannot be moved easily and large work cannot be easily manouvered onto a drill press.

Portable drills are manufactured in several sizes. The 6 mm ( $\frac{1}{4}$  inch), 9 mm ( $\frac{3}{8}$  inch) and 12 mm ( $\frac{1}{2}$  inch) sizes are the most common. The size is determined by the maximum diameter of drill shank that can be fitted into the chuck.

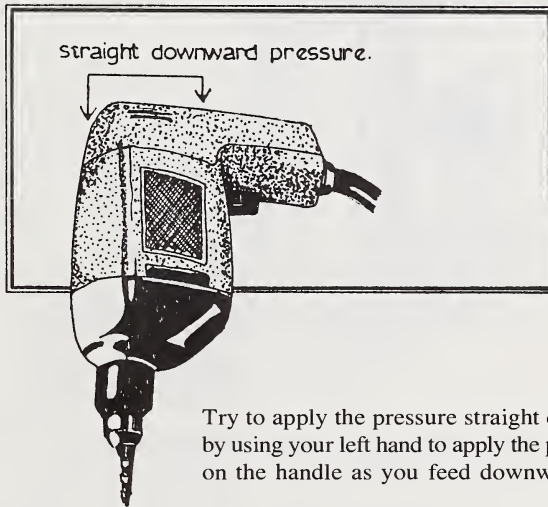
In the section of this lesson dealing with the drill press, drill speeds were discussed. At that time it was noted that small drills should be turned at high speeds and large drills turned at lower speeds. This idea is applied to the design of portable drills. The 6 mm electric drill rotates at a high speed, the 9 mm at a slower speed and the 12 mm drill at a very slow speed. For this reason it is best to use a 6 mm portable drill for small holes, the 9 mm drill for medium sized holes, and the 12 mm drill for the larger holes.

The following procedures are important to remember when using a portable electric drill.

- (i) Make sure to unplug the drill before installing or removing a bit from the chuck.
- (ii) Before starting to drill a hole in metal, the spot where the drill is to be started should be centre punched so the drill does not wander.
- (iii) Apply pressure straight down onto the bit. This could involve some twisting of the handle when using a small drill with the handle on the side.



downward pressure here results in side force on the bit here.



Try to apply the pressure straight downward. This can be done by using your left hand to apply the pressure or by twisting slightly on the handle as you feed downward.

- (iv) Small drills do not require nearly as much feed pressure as large drills. Do not let a dull drill fool you into applying too much pressure as this can easily break a drill bit.
- (v) Always keep loose clothing, sleeves, ties, etc. away from the drill.
- (vi) Never use power tools of any kind while standing in water or on wet ground.
- (vii) Always secure the work to be drilled. If the drill grabs and the work is loose, it can begin to spin, resulting in a serious cut.
- (viii) Use eye protection whenever removing material (drilling, grinding, etc.).

Prior to starting a hole in metal, the location of the center of the hole must be located and marked. Center punch this location so the twist drill will not wander as drill feed pressure is applied.

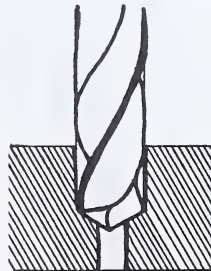


LARGE CENTRE MARK

MAKE SURE THE DRILL HAS A GOOD START

For larger drills, the feed pressure is considerably more than for small drills. The amount of pressure required for making large holes can be reduced by drilling a smaller pilot hole first.

### (c) Grinders



USE A PILOT HOLE BEFORE A  
LARGER DRILL

Bench grinders are commonly used to sharpen tools and remove stock from various parts. Gasket scrapers are sharpened on a bench grinder.

Several precautions are required to be followed when operating bench grinders. These are:

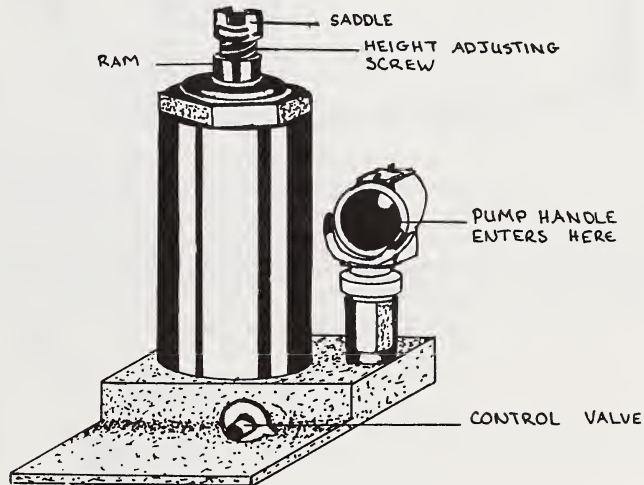
- (i) Always wear goggles.
- (ii) Stand to one side of the grinding wheels while the grinder is reaching full speed. Grinding wheels will sometimes disintegrate while coming up to full speed. As well, stand to one side of the wheels as much as possible while grinding.

- (iii) Keep the tool rest as close to the wheel as possible to prevent the tool being sharpened from jamming between the tool rest and the grinding wheel.
- (ic) Hold small objects with vice grip pliers rather than by hand to prevent injury to your hand.

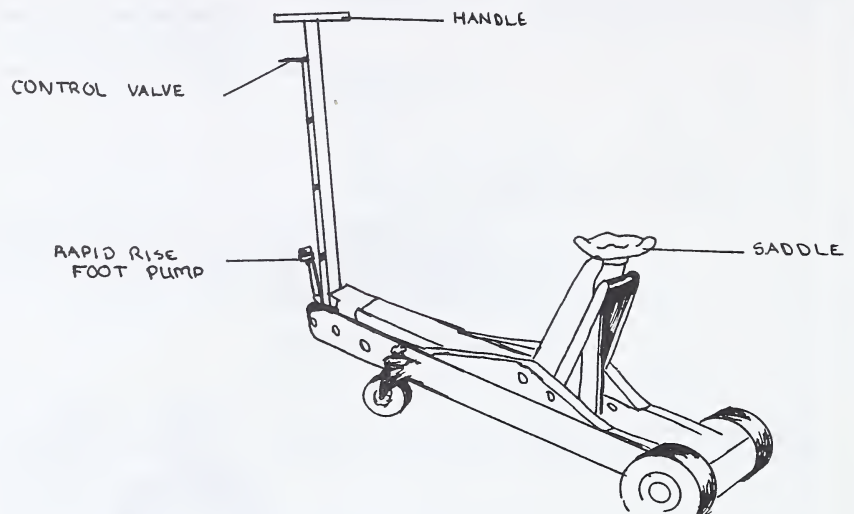
## 2. Lifting Equipment

A wide assortment of lifting equipment is available in most garages. Extreme care must be used in operating any lifting equipment. Never use any type of lifting equipment without first receiving instructions on its use.

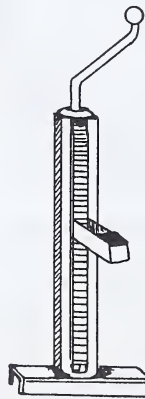
### (a) Hydraulic Hand Jack



The hydraulic jack is used to support or raise heavy loads. It is short and compact and can be used in smaller spaces. Its primary use is for raising an axle when changing tires.

**(b) Hydraulic Floor Jack**

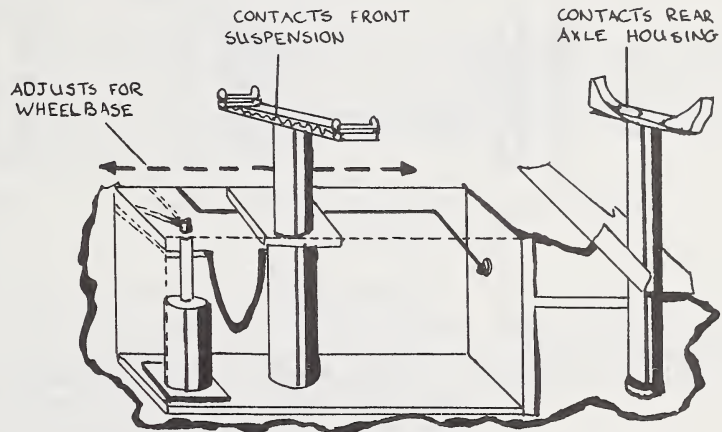
The hydraulic floor jack is used to raise the front, back, or side of a vehicle. When positioning the jack saddle, select a spot which will be strong enough to support the load. Never try to raise a vehicle by placing the jack under the oil pan, clutch housing, transmission, etc. Insure the jack saddle will not slip out of position. Any slippage can cause serious damage.

**(c) Vehicle Bumper Jack**

This is the jack supplied with most automobiles. It is used solely for tire changing. Carefully follow the vehicle manufacturer's directions for using the bumper jack. Always block the wheels on the opposite end to prevent the vehicle from rolling off the jack. Also set the vehicle's emergency brake before lifting.

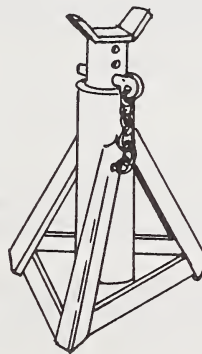
**(d) Vehicle Lifts**

Several styles of vehicle lifts are available. One type called a double post suspension lift is shown below.



Vehicle lifts are usually operated by compressed air.

**Never crawl under vehicles supported by jacks or by vehicle lifts alone.** They may malfunction and the vehicle could fall and crush you. Jack stands (axle stands) are safety devices placed under the vehicle to properly and safely support it while you work under the vehicle.

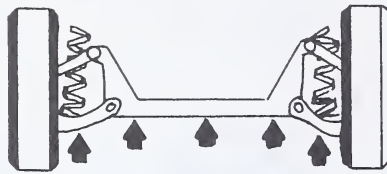


JACK STAND (ALSO CALLED AN AXLE STAND)

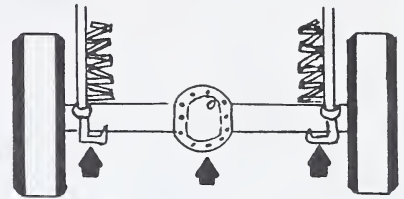
Vehicle lifts usually have their own safety support system built into them. Make sure these safety systems operate properly.

Jacks and lifts must always be positioned properly or severe damage to the vehicle may result.

Suggested lifting points for hand jacks, jack stands, floor jacks and vehicle lifts are shown below.



SUGGESTED LIFTING POINTS ON THE FRONT OF A VEHICLE



SUGGESTED LIFTING POINTS ON THE REAR OF A VEHICLE

Bumper jacks must be positioned according to the vehicle manufacturer's recommendations.

Other special lifting devices are in use by mechanics. They include transmission jacks, chain hoists, portable cranes for lifting engines, and more. Before using these be sure you know how to use them properly. Never use machines before having a competent person demonstrate how to operate them safely.

### 3. Compressed Air

Compressed air is used in all commercial garages to inflate tires and to power equipment such as air impact wrenches and tire changers.

Although compressed air may be taken for granted, it can be extremely dangerous. This is indicated below in the safety letter from "The Workers' Compensation Board of Alberta."

#### Use Compressed Air With Care

"Horseplay" is defined in the dictionary as being rough or boisterous play but it develops into more than play when there is the possibility of serious injury to workmen or interference with job procedure.

Years ago "horseplay" was confined to the new employee such as sending him for a left-handed monkey wrench or a pail of hot steam. Today the mild jokes have given way to pranks of a more serious job hazard often resulting in injury, even death.

A number of cases are on record of "horseplay" involving the use of compressed air where its lethal aspects were not understood. Just 30 kPa (4.5 lbs/in<sup>2</sup>) of direct air pressure will rupture the bowel. 300 kPa (45 lbs/in<sup>2</sup>) of air pressure released from the nozzle of an air gun passing 10 cm (4 in) from the ear can cause rupture of the ear drum and possibly cerebral hemorrhage resulting in death. The same distance from the eyes can cause blindness and this pressure and distance from the mouth can rupture the lungs, stomach or intestines.

Although the body openings are vulnerable so are slight scratches or punctures of the skin which permit entrance of air under pressure. The affected part immediately swells to huge proportions and becomes extremely painful. Once air gets into the blood stream it can make its way to the small blood vessels in the brain and cause death.

Workmen should wear eye protection when using compressed air. If blowing shavings, dust, chips or filings from machines the air under pressure can blow them back toward the operator. It has been estimated that steel filings with 300 kPa (45 lbs/in<sup>2</sup>) of air pressure behind them travel at a speed in excess of 110 km/h (70 miles/h).

## **WORKERS' COMPENSATION**

Workers Compensation is intended to protect and assist workers who suffer injury or disablement due to work-related accidents or fall ill from work-related diseases. Workers' Compensation is governed in Alberta by the Workers' Compensation Act of Alberta and administered by the Workers' Compensation Board.

Employers also have protection through Workers' Compensation. In return for paying assessments, employers are protected against legal action by workers who are injured or contract industrial disease during the course of employment.

### **1. Benefits**

If a disabling injury results from an accident occurring during employment or if a disabling disease or potentially disabling disease is directly attributable to the employment, compensation is paid for as listed below.

- (a) All costs for basic health services, as defined in the Alberta Health Care Insurance Act, will be paid through the Alberta Health Care Insurance Plan.
- (b) Compensation paid will be 90% of wages (as determined by regulations in the Workers' Compensation Act), based on gross earnings, up to a maximum of \$40 000 per year. Maximum compensation for workers earning more than \$40 000 per year depends on the degree of disablement and worker's earnings.
- (c) Where a permanent disability results from an accident, a pension, based on the amount of disability and the worker's earnings at the time of the accident, will be awarded.
- (d) Dependents of a worker who dies as a result of an accident arising out of and in the course of employment are entitled to certain benefits relating to funeral expenses plus receiving a pension based on what the worker would have received had the accident resulted in permanent total disability.

## 2. Accident Reporting

Even though a person is safety conscious, occasional lapses may occur which lead to an accident. It can only be hoped that these accidents are minor in nature. However, for every accident occurring an accident report form should be filled out listing certain information pertaining to the accident. The type of accident form used may vary from one organization to another. However, usually a standard form offered through the Workers' Compensation Board is used.

Before the Workers' Compensation Board can determine whether an injured worker is entitled to compensation, it must have complete details of the accident. Properly completed accident report forms provide the necessary information. It is important that the employer keep a complete record of accidents, injuries suffered by employees, and any first aid treatment provided, even for minor injuries for which no claim is made at the time.

Accident reports are compiled and indicated in statistical form. Accidents are measured in terms of frequency, probability, medical costs, time lost from work, other costs, and other ways that are useful in identifying work hazards and developing safety programs.

Some safety is plain common sense but many other aspects of safety can only be learned from books, magazines, instruction booklets, and/or shop manuals. In today's scientific age more specific information is needed, not just common sense.

**SELF-CORRECTING EXERCISE 1**

Chose the letter of the best answer and place it in the space to the left of the question.

- \_\_\_\_\_ 1. A worker was lifting an engine cylinder head onto a bench when he felt a sharp pain in his lower back. This was the result of an \_\_\_\_\_.  
(a) unsafe act.  
(b) unsafe condition.  
(c) unsafe situation.  
(d) unlucky set of biorhythms.
- \_\_\_\_\_ 2. Close calls as far as accidents are concerned should be a warning to the worker. What type of warning are they?  
(a) They should be a warning for the worker to pay closer attention to his work.  
(b) They should be a warning to the worker that there are safer ways of doing the job.  
(c) They should be a warning that proper procedures are not being followed.  
(d) All of the above warnings apply.
- \_\_\_\_\_ 3. Why should you never walk under a suspended engine block?  
(a) The load may bump into a vehicle if you touch it.  
(b) You may get oil on yourself as you walk under the engine.  
(c) The lift cable could break and the load may fall on you.  
(d) The engine block may move out of position and hence may be difficult to reposition.
- \_\_\_\_\_ 4. 88% of accidents are caused by unsafe acts. Why?  
(a) Operators at times tend to get careless.  
(b) Newer machines are not as safe as older ones.  
(c) Both of the above answers are true.  
(d) Scraps left on the floor lead to many accidents.
- \_\_\_\_\_ 5. A worker was scraping an old gasket from a thermostat housing with a dull scraper. This is an example of an  
(a) unsafe act.  
(b) unsafe condition.

- \_\_\_\_\_ 6. Why are drill presses considered better than portable drills for making holes in metal?
- (a) Drill presses have more power.
  - (b) Drill presses supply more feed pressure easier than portable drills.
  - (c) The drill press head is always perpendicular to the work. This makes it easier to drill straight holes.
  - (d) Both (b) and (c) above are correct.
- \_\_\_\_\_ 7. A 12 mm diameter twist drill should be turned at 809 r/min when drilling in mild steel. What speed should a 6 mm diameter twist drill be turned at when drilling in the same material?
- (a) Twice as fast.
  - (b) Half as fast.
  - (c) The same speed.
  - (d) It does not matter what speed is used.
- \_\_\_\_\_ 8. What can be done to reduce the amount of feed pressure required to force large drills into the work?
- (a) Center punch the hole before starting to drill.
  - (b) Drill a pilot hole through the material first.
  - (c) Use a drill press.
  - (d) Both (a) and (b) help reduce the feed pressure required.
- \_\_\_\_\_ 9. Where do the funds required to operate Workers' Compensation come from?
- (a) employees
  - (b) both employees and employers
  - (c) employers
  - (d) government
- \_\_\_\_\_ 10. Why is moving equipment suddenly, without letting others in the area know, considered a dangerous act?
- (a) Sudden movement of equipment is a distraction to other workers.
  - (b) Sudden movement of equipment can cause damage to the equipment.
  - (c) Sudden movement of equipment should never cause problems.
  - (d) Workers could get injured trying to find out where the equipment was moved to.

- \_\_\_\_\_ 11. Why should you never use a class A fire extinguisher on gasoline fires?
- (a) Class A chemicals may combine with the gasoline to create a dangerous chemical.
  - (b) Class A fire extinguishers will not control the fire but may cause it to spread.
  - (c) Class A fire extinguishers are too small in capacity to handle gasoline fires.
  - (d) Class A fire extinguishers must be pumped out by hand and this makes them too slow to control gasoline fires.

## SELF-CORRECTING EXERCISE 2

Define the following terms as used in this lesson.

1. Unsafe act

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2. Unsafe condition

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3. Shock

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4. Center Punch

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5. Accident

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Complete the following exercise and send it in for correction.

**EXERCISE 1**

1. Why should you never operate a machine until you have been given a demonstration on how to operate it?
2. Why is it extremely poor practice to walk up behind a worker and tap him on the shoulder to get his attention?
3. Why is it important to keep work areas clean?
4. Give two advantages of a drill press over a portable electric drill.

(a)

(b)
5. Give two advantages of a portable electric drill over a drill press.

(a)

(b)
6. Why should you **never** work under a vehicle supported only by a floor jack?

7. A mechanic noticed a fire had started in a tool storage room. List in order the five major steps he should follow.

- (a) \_\_\_\_\_
- (b) \_\_\_\_\_
- (c) \_\_\_\_\_
- (d) \_\_\_\_\_
- (e) \_\_\_\_\_

8. What does the following symbol represent?



\_\_\_\_\_

9. Why should goggles be worn when using a bench grinder?

\_\_\_\_\_

\_\_\_\_\_

10. Why should a worker not use compressed air to clean off the uniform she is wearing after completing a job?

\_\_\_\_\_

\_\_\_\_\_

11. Give one reason why an accident report should be filled out, even if a minor accident occurred.

\_\_\_\_\_

\_\_\_\_\_

**ANSWERS TO SELF-CORRECTING EXERCISES****Self-Correcting Exercise 1**

- |                    |                       |
|--------------------|-----------------------|
| 1. a (page 2)      | 7. a (page 17)        |
| 2. d (page 7)      | 8. b (page 20)        |
| 3. c (page 3)      | 9. c (page 25)        |
| 4. a               | 10. a (pages 2 and 4) |
| 5. a (page 2)      | 11. b (page 8)        |
| 6. d (pages 16-17) |                       |

**Self-Correcting Exercise 2**

- |            |            |
|------------|------------|
| 1. page 2  | 4. page 20 |
| 2. page 5  | 5. page 1  |
| 3. page 11 |            |

**END OF LESSON 4**



# LESSON RECORD FORM

1746 Mechanics 12

Module 1

## FOR STUDENT USE ONLY

Date Lesson Submitted

\_\_\_\_\_

Time Spent on Lesson

\_\_\_\_\_

(If label is missing  
or incorrect)

File Number

\_\_\_\_\_

Lesson Number \_\_\_\_\_

## Student's Questions and Comments

Apply Lesson Label Here

Name \_\_\_\_\_

Address \_\_\_\_\_

Postal Code \_\_\_\_\_

*Please verify that preprinted label is for  
correct course and lesson.*

## FOR SCHOOL USE ONLY

Assigned

Teacher: \_\_\_\_\_

Lesson Grading: \_\_\_\_\_

Additional Grading

E/R/P Code: \_\_\_\_\_

Mark: \_\_\_\_\_

Graded by: \_\_\_\_\_

Assignment Code: \_\_\_\_\_

Date Lesson Received:

\_\_\_\_\_

Lesson Recorded \_\_\_\_\_

Teacher's Comments:

## **ALBERTA DISTANCE LEARNING CENTRE**

### **MAILING INSTRUCTIONS FOR CORRESPONDENCE LESSONS**

#### **1. BEFORE MAILING YOUR LESSONS, PLEASE SEE THAT:**

- (1) All pages are numbered and in order, and no paper clips or staples are used.
- (2) All exercises are completed. If not, explain why.
- (3) Your work has been re-read to ensure accuracy in spelling and lesson details.
- (4) The Lesson Record Form is filled out and the correct lesson label is attached.
- (5) This mailing sheet is placed on the lesson.

#### **2. POSTAGE REGULATIONS**

Do not enclose letters with lessons.

Send all letters in a separate envelope.

#### **3. POSTAGE RATES**

First Class

Take your lesson to the Post Office and have it weighed. Attach sufficient postage and a green first-class sticker to the front of the envelope, and seal the envelope. Correspondence lessons will travel faster if first-class postage is used.

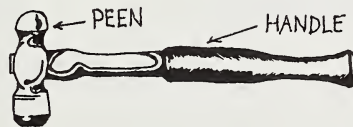
Try to mail each lesson as soon as it has been completed.

When you register for correspondence courses, you are expected to send lessons for correction regularly. Avoid sending more than two or three lessons in one subject at the same time.

**TOOLS AND MEASURING INSTRUMENTS****Hand Tools  
Measuring Instruments****HAND TOOLS**

For the most part this lesson is in the form of a dictionary of tools. A picture (or sketch) as well as a brief description of the application of each tool is included. Where necessary a more detailed description has been included.

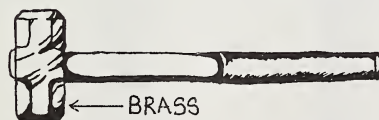
Return to this lesson often and review the names and uses of the tools. Before completing the course, you should know the names and uses for **all** of the tools mentioned. This is by no means a complete list of mechanics tools. There are a great variety of specialized tools available. Only the most commonly used tools have been included in this lesson.

**1. Hammers****(a) Ball peen hammer**

The ball peen hammer is used for all general hammering, riveting, and gasket cutting. This hammer is often used for pounding on chisels or punches.

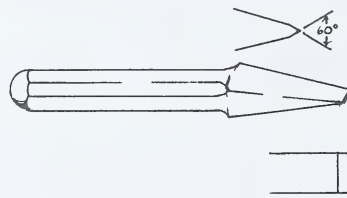
**(b) Plastic tip hammer**

This hammer is used to prevent any marring of parts when striking is necessary to remove or install them. Do not use heavy blows or strike sharp corners since damage could result to the plastic tip.

**(c) Brass hammer**

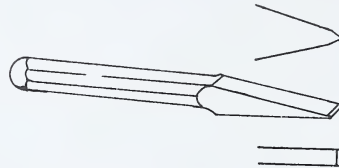
This hammer is also used to prevent marring of parts. Again do not pound with heavy blows or on sharp edges in order to prevent damage. This hammer is heavier than plastic tipped hammers and used when more force is required to assemble or disassemble parts.

## 2. Chisels (also called cold chisels)



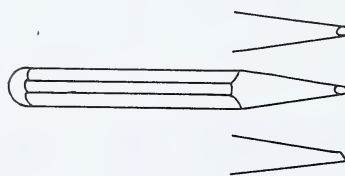
### (a) Flat chisel

The flat chisel is used for general cutting and chipping work. It is the most commonly used chisel.



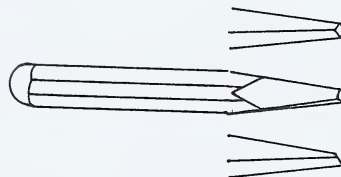
### (b) Cape chisel

A cape chisel has a narrower cutting edge than a flat chisel. The cape chisel is used for cutting grooves and keyways.



### (c) Round-nose chisel

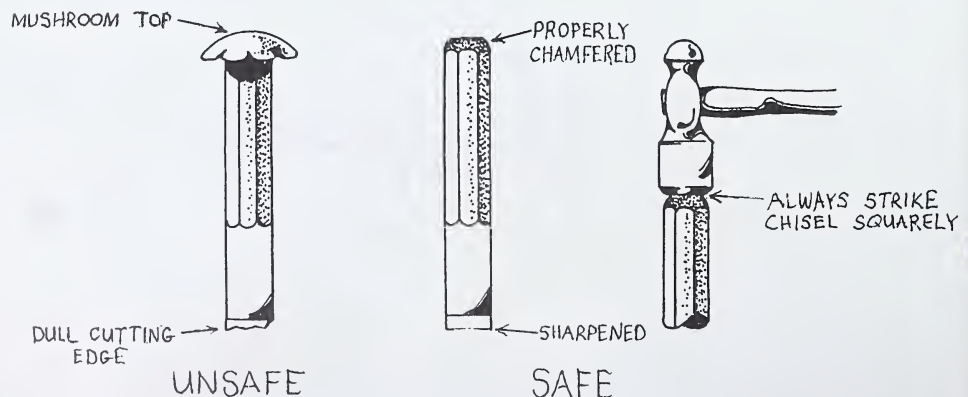
This chisel is used to cut round grooves or to move a drilled hole that was started in the wrong location.



### (d) Diamond-point chisel

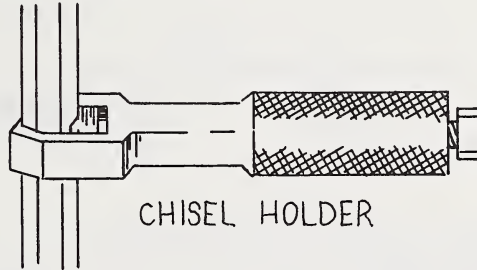
This chisel is used for cleaning out square corners or cutting a sharp bottomed groove.

In order to be safe, chisels must be properly looked after. Chisels which are allowed to form mushroomed heads are extremely dangerous. A mushroomed head can chip when hit and release rapidly moving chunks of metal which could easily damage an eye. The eye could be permanently damaged causing blindness.



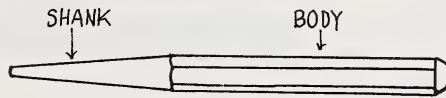
The mushroomed top can be removed using a bench grinder. Make sure that all proper procedures are followed when grinding a mushroomed chisel head.

The cutting edge of the chisel can be sharpened at the same time that the mushroomed head is removed. **Do not** allow the cutting edge to overheat while grinding. If the edge turns blue-black in color, some hardness will have been removed from the cutting edge. In future this chisel would dull more quickly. To prevent overheating grind the cutting edge slowly, and cool it often in water.



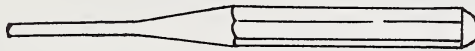
Chisel holders are sometimes used as a safety measure. They help prevent painful injuries caused by the hammer missing the top end of the chisel and striking your fingers or hand.

### 3. Punches



#### (a) Starting punch

A starting punch is used to knock out rivets and to start or knock out pins.



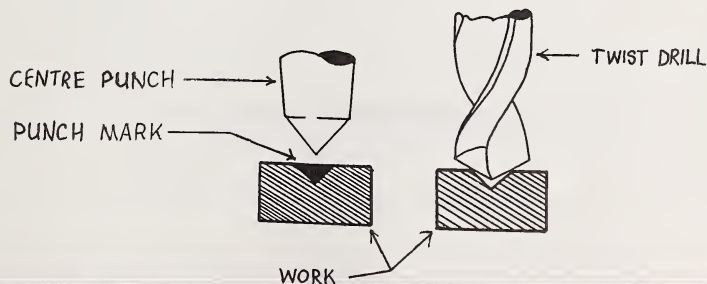
#### (b) Pin punch

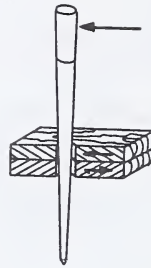
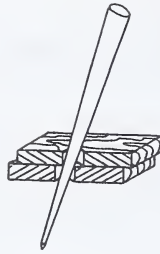
This punch is used for driving out pins after the starting punch can no longer be used. The slim shank of the pin punch may break if it is used to start a pin moving.



#### (c) Centre punch

The centre punch is used to make the centre of a hole that is to be drilled. The mark ensures that the drill will start cutting in the right spot and not wander.

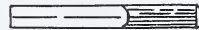


**(d) Aligning Punch**

This punch is used to line up corresponding holes in two pieces of material. Never use an aligning punch as a centre punch.



DRIFT PUNCHES



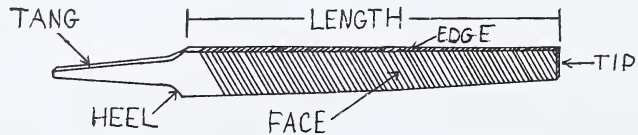
BRASS DRIFT

**(e) Drift Punches**

Drift punches are quite long and are used to reach hard-to-get-at spots and for lining up materials. Some drifts are tapered, while others, such as a brass drift, are a straight rod.

**4. Files**

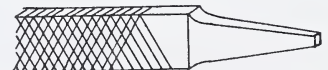
Files form an important part of a mechanics tool collection. Files are useful for removing nicks and burrs on parts before fitting them together.

**(a) File characteristics****(i) Tooth styles**

Files come with two styles of teeth. These differ in the manner the teeth are formed on the file.



SINGLE-CUT FILE



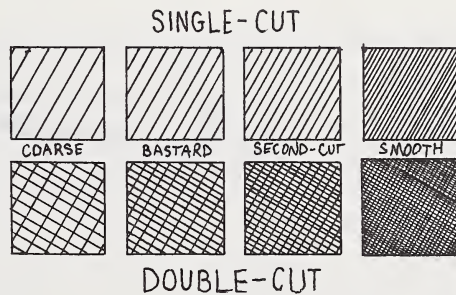
DOUBLE-CUT FILE

The single-cut file is generally used where a smoother surface is desired. They tend to cut slower than double-cut files but leave a smoother job. Single-cut files are used for sharpening tools and smoothing nicks from flat surfaces which are to be joined with a gasket.

The double-cut file is used for faster removal of metal. A double-cut file leaves a rougher finish and is generally used for jobs which do not require a smooth finish.

(ii) Tooth spacing

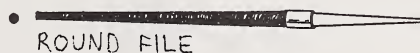
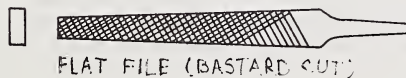
Files are also categorized according to tooth spacing (coarseness or fineness of the teeth).



The coarser teeth tend to remove material quicker, but leave a rougher surface.

(iii) File shape

Files are further classified according to shape. Some files are shaped for special jobs i.e. chain saw files for sharpening power saws, half round and round files for curved or irregular shapes. Other files are made for filing flat surfaces i.e. mill file, flat file.



(iv) File length

Files are available in lengths from 75 mm to 450 mm. The longer the file, the further the teeth are apart (the longer files are coarser). A mechanic usually purchases files which are from 250 mm to 350 mm in length.

**(b) The Use and Care of Files**

Before attempting to use any file, it should be equipped with a tight-fitting handle. If you attempt to use a file without a handle, and the file meets an obstruction and stops suddenly, the pressure of your hand against the tang may result in a serious cut.



Always clamp the work securely with the area to be filed as close to the vise as possible to prevent the work from vibrating. If the work vibrates, a file will chatter (dig in and then skip, dig in and then skip). This leaves a rough surface.

Apply downward feed pressure on the forward stroke only. Remember file teeth cut only one way (while moving forward). If downward pressure is applied on the return stroke, the file will dull much quicker than if pressure is removed while the file is being drawn back. Also only enough downward pressure should be applied to make the file cut. If too much or too little pressure is applied, the life of the file will be reduced.

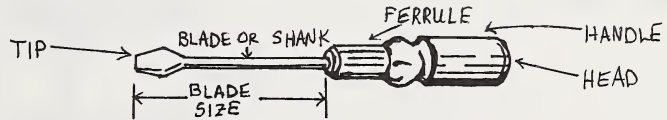
Keep the file clean. If file teeth become clogged with chips, the file will not cut as well as it should and it will leave scratches on the surface of the work. Blackboard chalk on file teeth will help keep them clean.

Store files carefully. If files are stored while wet, they will rust. Damp locations will also lead to files rusting. Once the teeth rust they will not cut as well as before since rust ruins the sharp cutting edges on the teeth.

## 5. Screwdrivers

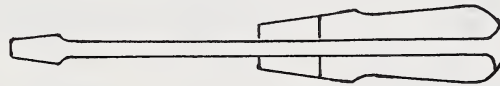
### (a) Handles

Screwdrivers are available in a variety of styles, tip shapes, blade lengths, and blade widths.



Handles are made of either wood or plastic. Some plastic handles have a rubber grip bonded onto them.

On some screwdrivers the blade runs completely through the handle. The reason for this is so one is able to pound on them without damage to the handle. Although screwdrivers are not intended for pounding on, some people do it.



Handles on other screwdrivers have the blade inserted only part way into the handle. This type should not be pounded on very hard.

The size of the handle is designed to suit the screwdriver blade. A small screwdriver only requires a small handle since a small machine screw requires only a small amount of force to install it. Large machine screws, on the other hand, require greater force to install and hence a larger screwdriver handle is necessary. A small machine screw can be easily twisted off or the threads stripped by using too large of a screwdriver on it.

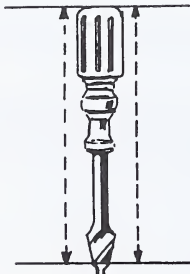
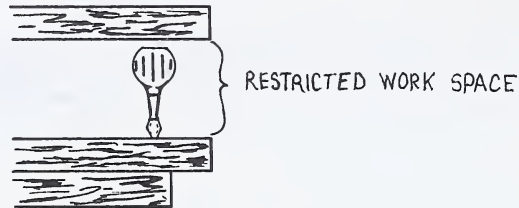
### (b) Shanks

The shank of most standard and light duty screwdrivers are round. On heavy duty screwdrivers, however, the shank is often square so that an open end wrench may be used for added turning power.



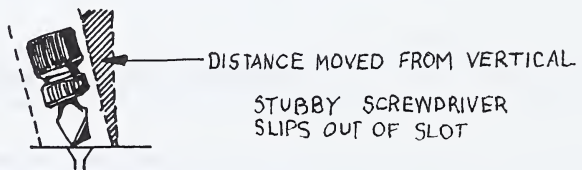
There are several different lengths of screwdrivers depending on their size and on which of the three categories of screwdrivers they belong to. The three categories are:

- (i) Stubby screwdrivers are used when installing machine screws in restricted places. Their overall length is 90 mm. They are available in any of the tip shapes (to be discussed later).



LONGER HEAVY DUTY  
SCREWDRIVER DOES NOT  
SLIP OUT OF SLOT

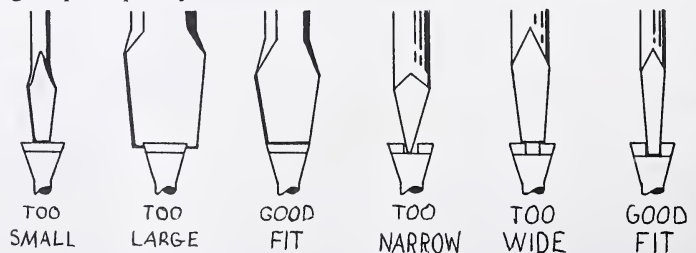
- (ii) Standard screwdrivers are available in any of the three tip shapes and are up to about 30 cm long.
- (iii) Heavy duty screwdrivers have lengths of blades up to 50 cm. They are available with standard (slot) tips. The longer the blade on a screwdriver, the easier it is to keep the screwdriver in the slot of the machine screw. The reason is that with a short stubby screwdriver it does not take much of a sideways movement of the handle before the screwdriver blade is at too great an angle to stay in the slot.



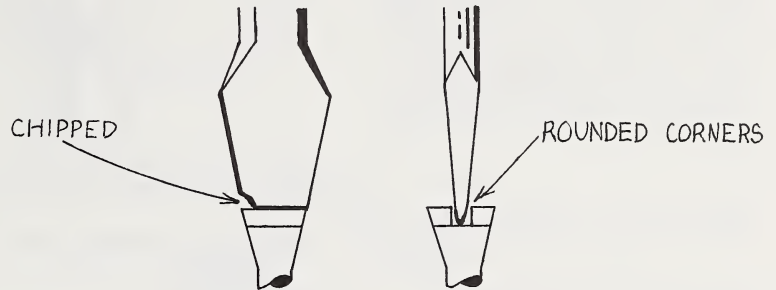
### (c) Types of Screwdriver Tips

There are several common screwdriver tip shapes.

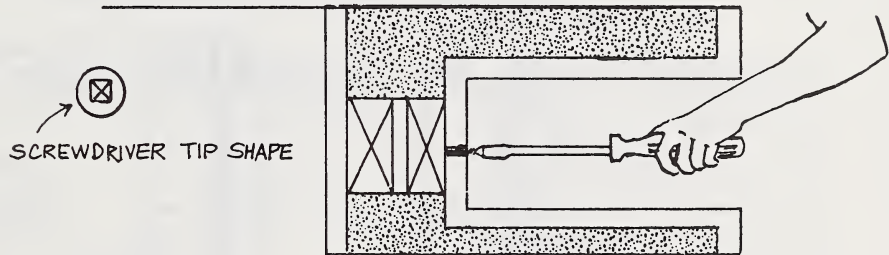
- (i) Slot tips (also called standard) are the oldest and most common types. They range from the very small jewellers screwdrivers to the cabinet, the standard, and the wide, thick heavy duty tips. It is especially important that the screwdriver fit the screw slot accurately, otherwise the screwhead becomes damaged quite quickly.



The screwdriver bit should be straight and square, not rounded and/or chipped. Rounded tips slip easily and damage screw slots and possibly the wood or metal itself.



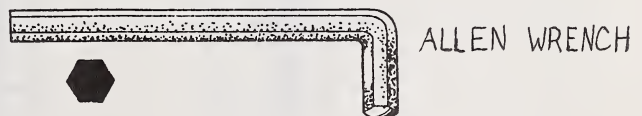
- (ii) Robertson (socket) tips are in the form of a square. The screwdriver does not slip sideways out of the screw head like a slotted screwdriver does. The screws will stay on the end of the screwdriver by themselves so that you can reach into a deep hard to get at place with one hand and install the machine screw.



- (iii) The Phillips tips are in the form of a star or cross. The screwdriver does not slip sideways out of the slot as easily as the standard (slot) type. This is especially important when using air or electric tools or when working in hard to reach areas. As with other screwdrivers, the size is given by the length of the blade and the size of the tip.

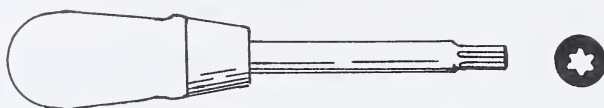


- (iv) Allen tips are hexagonal (six sided) in shape.



Many set screws have Allen slotted heads.

## (v) Torx tips



Torx tips are used on some vehicles for attaching trim, adjusting headlights, and holding seat belts firmly to the vehicle body.

There are several sizes of torx screwdrivers available.

**6. Socket wrench set**

Socket wrenches are one of the most commonly used wrenches. They are able to work in hard-to-reach places, plus allow the speedy removal of bolts or nuts.

Socket wrench sets come in several sizes. Common sizes are 6 mm ( $\frac{1}{4}$  inch), 9 mm ( $\frac{3}{8}$  inch), 12 mm ( $\frac{1}{2}$  inch), and 18 mm ( $\frac{3}{4}$  inch). This size is the length and width of the square opening in the back of the sockets.



6-POINT SOCKET



12-POINT SOCKET

**(a) Standard 6 point and 12 point sockets**

Standard sockets are shallow sockets designed to fit bolt heads and nuts where only a few threads protrude through the nut.

Six point sockets contact the sides of hexagonal nuts and tend to be stronger and less likely to slip.

6-POINT  
DEEP SOCKET12-POINT  
DEEP SOCKET**(b) 6 point and 12 point deep sockets**

The extra reach of the deep socket is useful for removing spark plugs or for removing nuts from bolts when the bolt length would prevent the use of standard sockets.



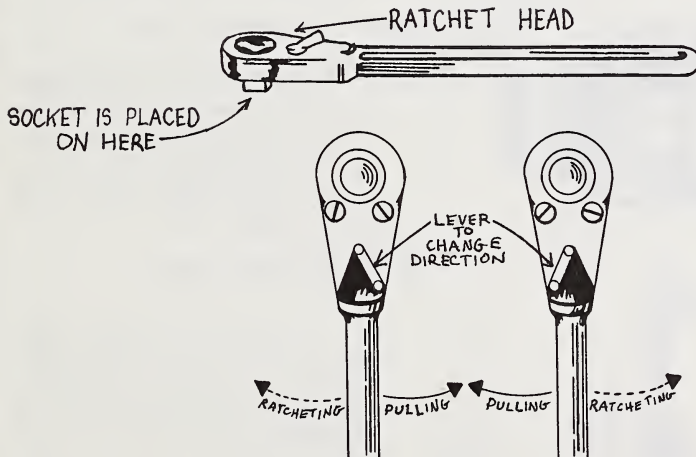
(c) **Spark plug sockets**

These sockets are similar to deep sockets in appearance. The difference is that spark plug sockets have a rubber insert inside the socket to hold the porcelain insulator of the spark plug and prevent breakage of it.



(d) **6 and 12 point swivel (or flex) sockets**

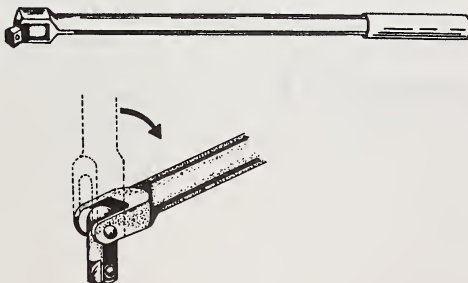
Flex sockets are used to reach into hard to get at areas. This type of socket is not very common as most people will use a universal joint and a standard socket in place of swivel sockets.



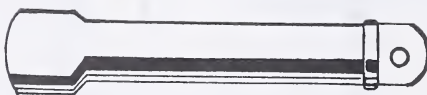
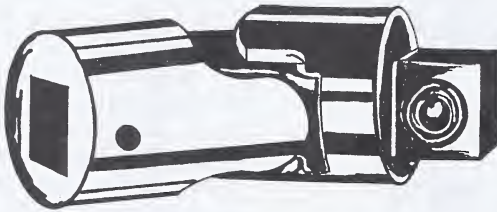
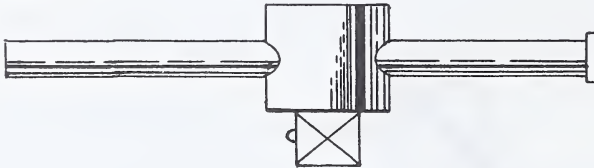
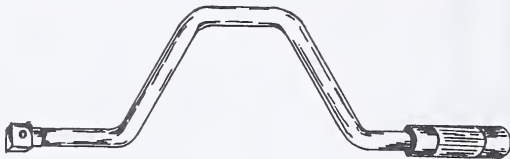
(e) **Socket ratchet handle**

To use the socket wrench place the correct size of socket onto the square end of the ratchet handle, and place the socket on the nut. Inside the head of the ratchet handle is a pawl (or dog) which engages one of the ratchet teeth. When pulling on the handle in one direction the pawl engages and turns the socket. Moving the handle in the other direction causes the pawl to lift over the teeth. This permits the handle to move back without turning the socket. On most ratchets there is a lever to change the direction of ratcheting.

(f) **Socket flex handle**



The socket flex handle is used to loosen tight nuts or bolts. It has a longer handle shaft than the ratchet in order to provide the greatest possible leverage when placed at a 90° angle to the socket. Once the nut is loosened the handle can be moved to the vertical position and twisted by one's fingers to completely remove the bolt or nut.



### (g) Socket speed handle

The speed handle is similar to a brace which a woodworker would use to bore holes. For example, a speed wrench will remove cylinder head bolts in a hurry after they have been loosened with a socket flex handle. They are also handy for quick removal of oil pan bolts where many fasteners are involved.

### (h) Socket sliding T handle

This handle can be used as a socket flex handle or the extension bar can be moved to the center to make a T handle.

### (i) Socket spinner handle

The socket spinner handle is used with small sockets for removal of machine screws and nuts.

### (j) Socket universal joint

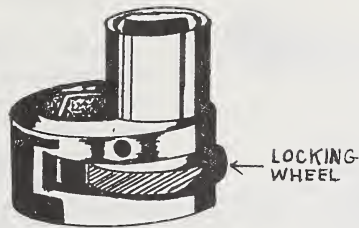
A universal joint is frequently used when working on nuts in places where a regular wrench cannot be used. The universal joint allows you to work the wrench handle at an angle with the socket.

### (k) Socket drive adapter

The socket drive adapter allows the use of one size of socket with another size of ratchet. For example, a 6 mm ( $\frac{1}{4}$  inch) drive socket can be used with a 9 mm ( $\frac{3}{8}$  inch) ratchet handle with the aid of a drive adapter. There are various sizes of drive adapters available.

### (l) Socket extension bars

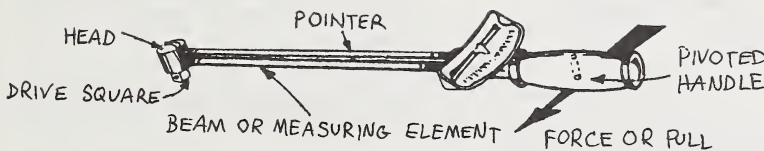
The extension bar is used to move the ratchet handle outward to an area where it can turn without interference. The extension bar is also used to allow sockets to extend into hard to reach areas.



### (m) Socket stud wrench

A stud is a fastener which has threads on both ends. As there is no head, studs require special techniques and/or special tools to remove them. The stud wrench slips over the stud and, as the ratchet or flex handle is turned, the locking wheel or wedge tightens against the stud. This tool allows for easy removal or reinstallation of studs.

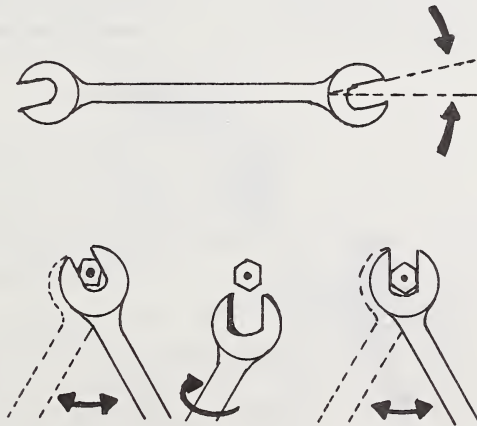
### (n) Torque wrench



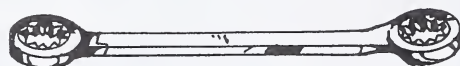
Nuts such as those used on the cylinder head or main bearing caps should be tightened to within certain limits. The amount of torque or twisting force to be applied is usually specified in the manufacturer's service manual. A torque wrench indicates how much torque or twisting force is applied to the bolt.

## 7. Other wrenches

### (a) Open end wrenches



Open end wrenches have openings at either end which are different sizes (but close in size). As the size of the wrench openings increase, the length of the wrench increases. This helps prevent overtightening or breakage of small bolts. The angle of the open end is at  $15^\circ$  to the body of the wrench. This allows the user to "flop" the wrench when working in tight spots. See the diagram at the left. The advantage of open end wrenches is that they can be repositioned quickly and hence the bolt can be removed faster.

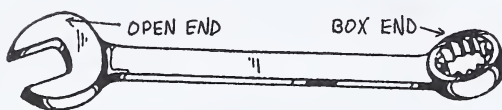


### (b) Box end wrenches

Both 6 and 12 point box end wrenches are available. Twelve point box end wrenches are most popular since they only require 15° of swing. Box end wrenches are available in double offset styles and 15° offset styles as shown to the left. Box end wrenches will not slip off a nut since they completely surround the nut.

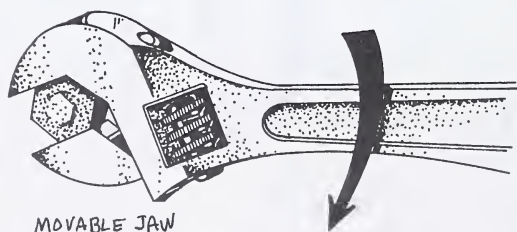
Remember to never push on a wrench. If a bolt "breaks loose", your knuckles will be scraped as your hand travels forward. Always pull on wrenches.

### (c) Combination box and open end wrenches



Combination wrenches can speed up removal of bolts. The box end can be used to "break loose" the bolt, then the open end can be used to quickly remove the bolt. With a combination wrench you have all the advantages of both a box end wrench and an open end wrench. This is the reason combination wrenches are the most popular type of wrenches in use today.

### (d) Adjustable wrenches



The term adjustable wrench refers to a wrench shaped somewhat similar to an open end wrench but having one adjustable jaw.

Adjustable wrenches are not intended to take the place of standard open end wrenches. They are, however, used for odd sized nuts or for emergency service work where full wrench sets are not available.

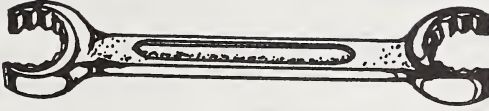


When applying a larger force to an adjustable wrench, always position the wrench on the nut so the pulling force is applied to the stationary jaw side of the handle. See the diagram to the left.

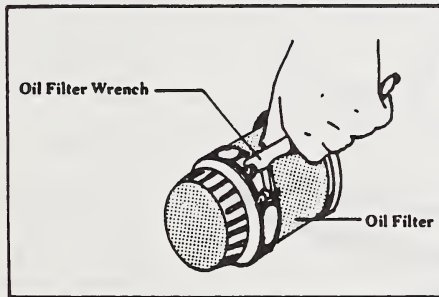
Also, after the wrench is placed on the nut, tighten the adjusting knurl so the jaws fit the nut firmly.

(e) **Flare nut wrenches**

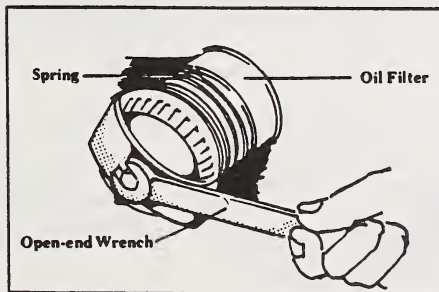
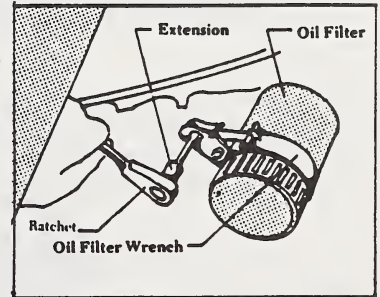
Flare nut wrenches have an opening in the end large enough to slide over pipe or tubing. Once over the tube this wrench is slid onto the fitting nut. It is much less likely to round the corners of a brass fitting than a standard open end wrench. Flare nut wrenches are useful for gas lines and oil cooler tubes on automobiles.



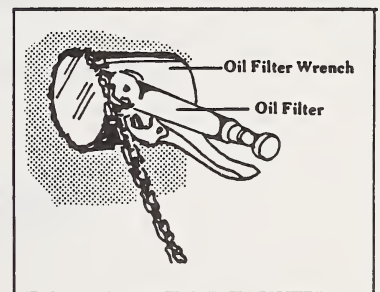
(f) **Oil filter wrench**



Strap type  
oil filter  
wrenches



Coil-spring wrench fits different size filters. Spring grips filter when wrench is turned counterclockwise.



Chain-type wrench fits all filters and gives tightest grip.

Oil filter wrenches provide a quick and efficient method of removing oil filters from vehicles. Some oil filter wrenches require more room to maneuver than others. Also some oil filter wrenches grip the filter better than others. It is best to choose a heavy duty oil filter wrench.

## 8. Pliers

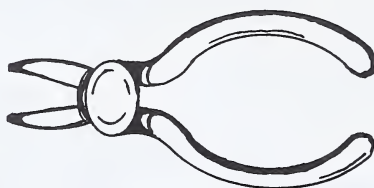
Pliers are not to be used in place of the proper type of wrench. They are not to be used for tightening or loosening fasteners since they will round corners. Pliers are used for holding parts, cutting wire, crimping connections, bending cotter pins, etc.

### (a) Combination slip joint pliers



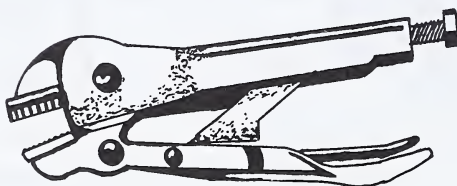
The combination slip joint pliers are general purpose pliers. They are used for holding parts, removing cotter pins and sometimes for cutting wire although other styles of pliers are better suited for this job.

### (b) Diagonal cutting pliers



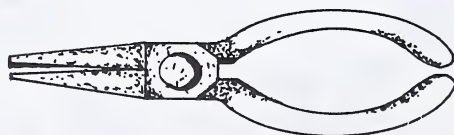
These pliers are used for cutting wires, removing cotter pins, cutting cotter pins to length, and for spreading cotter pins once they have been installed.

### (c) Vise grip or plier wrench



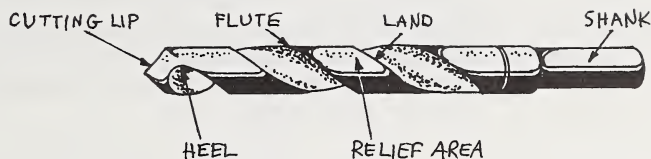
These pliers apply spring loaded pressure and lock in position. They do not require a constant squeezing pressure to hold them onto the work. Vise grip pliers are used for holding parts in position or gripping parts when pulling them out or removing them.

### (d) Needle nose or long nose pliers



These pliers are handy for reaching into hard to get at places when installing or removing parts.

## 9. Twist Drills



The better quality **twist drills** are made of high speed steel and are better for drilling holes in most metals. They can be readily sharpened without losing their temper (hardness), if overheated.

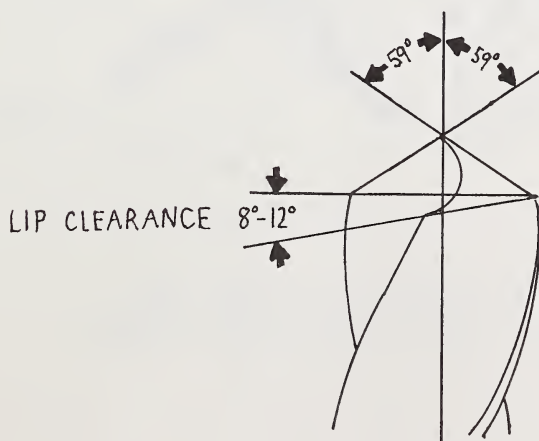
Other twist drills are made of carbon steel. They are less expensive but require frequent sharpening and they lose their temper (hardness) if overheated. Once they lose their temper, carbon steel drills will not stay sharp and they become useless. Also carbon steel twist drills cannot be used to drill harder steel. They will not cut into the steel since the hard steel will dull their cutting edges.

The mechanic has many uses for twist drills. They can be used for drilling holes to mount new accessories. Another use is for drilling holes into broken fasteners. An "easy out" is then inserted in the hole. It grips the sides of the hole and allows the broken fastener to be removed. Further information on "easy out" can be found later in this lesson.

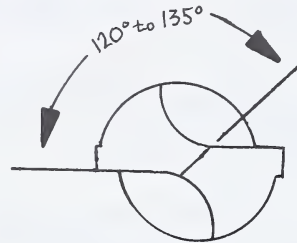
In order to perform satisfactorily, twist drills must be sharp. If the drills are not sharp then they will have to be sharpened, usually using a grinder. Before proceeding to the actual sharpening operation, have a knowledgeable person demonstrate the safe operation of the grinder.

When sharpening a twist drill three factors must be considered:

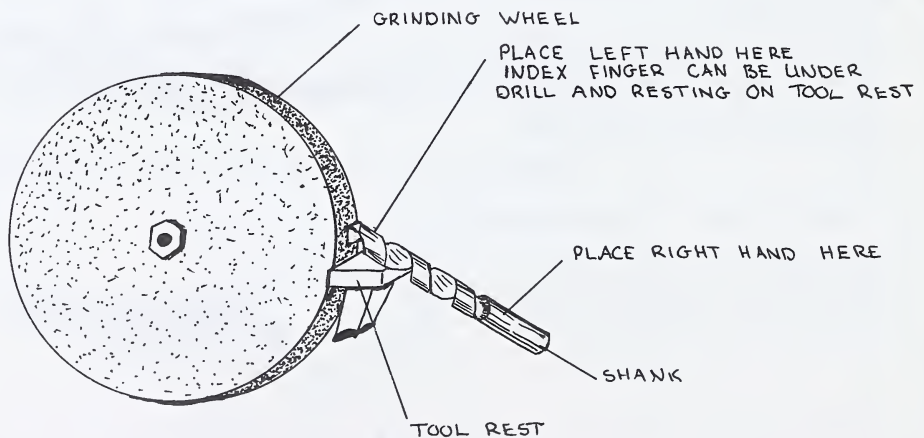
- (a) First, lip clearance must be considered.



The two cutting edges or lips are comparable to chisels. To cut effectively, the heel or that part of the point back of the cutting edge must be relieved. Without this clearance, it would be impossible for the lips to cut. If there is too much clearance cutting edges are weakened. Too little clearance results in the drill point merely rubbing without penetration. Gradually increase lip clearance toward the centre until the line across dead centre stands at an angle of 120 to 135 degrees with the cutting edge.

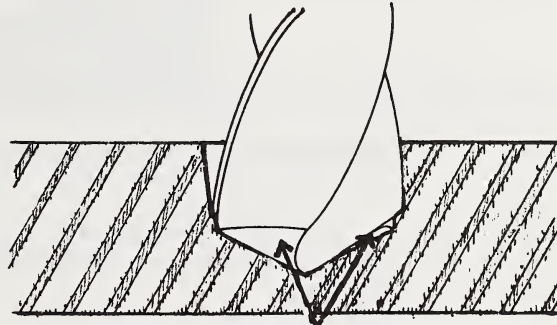


To do the grinding, grasp the drill shank in your right hand and the remainder of the drill in your left hand. Place the fingers of the left hand (the hand supporting the drill) on the grinder tool rest. The tool rest should be slightly below centre (about 25.4 mm (1 inch) on a 175 mm (7 inch) grinding wheel.



- (b) Next length and angle of lips must be considered.

The material to be drilled determines the proper point angle. The angles, in relation to the axis, must be the same. Fifty-nine degrees has been found satisfactory for most metals. If the angles are unequal only one lip will cut and the hole will be oversize.



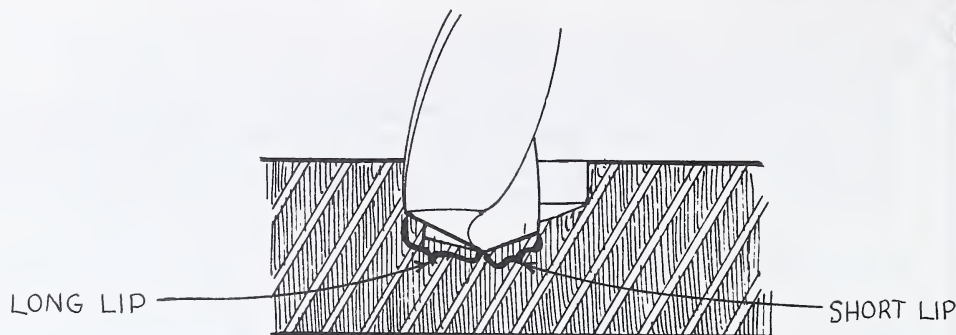
UNEQUAL DRILL POINT ANGLES

In order to get the correct drill point angles, stand so the centre line of the drill will be at a  $59^\circ$  angle to the centre line of the grinding wheel. Hold the drill in a horizontal position. Use the left hand as a pivot point and slowly lower the shank with the right hand. Increase the pressure as the heel is reached to insure proper clearance. Repeat the operation on each lip until the drill is sharp. Use a drill point gauge to check for the proper  $59^\circ$  angle.



- (c) The third item to consider is the proper location of the dead centre.

Equal angles but lips of different lengths will result in oversize holes and the resulting "wobble" places tremendous pressures on the drill press spindle and bearings. Regrind if necessary to get equal length lips.



**Warning:** Do not quench high speed drills in water. Let them cool slowly. If these instructions are followed, a sharp fast cutting drill will be the result.

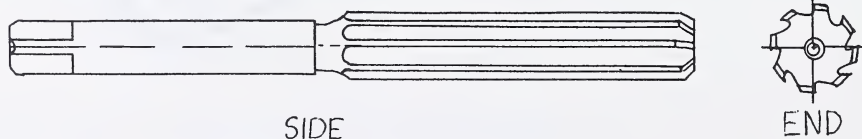
Twist drills will wander off the mark when starting a hole so it is recommended that the starting mark be centre punched. This is explained in the section on centre punches.

Once a hole is started, it is important to keep the twist drill cutting. As long as chips are being produced by both cutting lips, the drill will stay sharp. If the drill is allowed to rub on the steel without cutting, it will dull quickly. Hence, it is important to apply sufficient pressure to keep the twist drill cutting. Remember though that as a drill dulls, more pressure is required to make it cut. If too much pressure is placed on small drills, they will break.

The larger a twist drill the more pressure that is needed to feed it into the work. With 12 mm drills this feed pressure can be greater than can be applied to a portable drill. In this case a smaller pilot hole (4 mm) can be made first. Then follow this pilot hole with the 12 mm drill. The required feed pressure will not be considerably less.

## 10. Reamers

A drill does not produce a smooth or accurate enough hole for a precision fit. Reaming is an operation which produces smooth holes finished to a standard size.



When a very accurate hole is required, the hole is first drilled a little undersized with a twist drill. The hole is then reamed to the correct size.

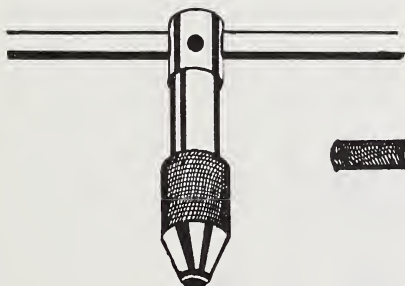
A hand reamer is turned by placing a tap wrench (discussed in the next section) onto the square end and then turning the reamer into the hole. Do not attempt to turn a reamer backwards as chips will jam against the back of the teeth and the side of the hole. Always turn reamers clockwise.

## 11. Cutting Threads

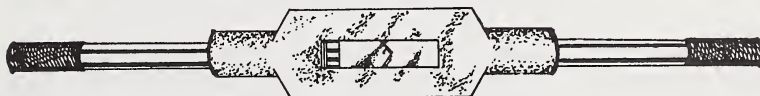
### (a) Tap



A tap is a tool used for cutting threads into a hole (cutting internal threads). The tap is held using a tap wrench. A T-tap wrench is used for small taps and a bar type tap wrench is used for larger taps.



T-TAP WRENCH



BAR TYPE TAP WRENCH

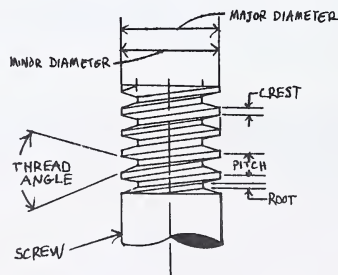
A hole must be drilled to the proper size before cutting threads. A Tap Drill Chart is used to choose the correct twist drill size. A Tap Drill Chart is shown on the next page.

## Metric Tap-Drill Chart Sizes

Nominal Diameter (Major Diameter) (mm)	Pitch	Tap drill diameter (mm)
1	.25	0.75
1.2	.25	0.95
1.4	.30	1.10
1.7	.35	1.30
2	.40	1.55
2.2	.45	1.85
2.5	.45	2.10
3	.50	2.55
3.5	.60	2.90
4	.70	3.30
4.5	.75	3.75
5	.80	4.25
6	1.00	5.10
7	1.00	6.10
8	1.25	6.80
10	1.50	8.50
12	1.75	10.25
14	2.00	12.00
16	2.00	14.00
18	2.50	15.50
20	2.50	17.50
22	2.50	19.50
24	3.00	21.00

Metric threads are classified by the major diameter of the thread and the pitch of the thread (distance from one thread to the same point on the next thread). For example, a  $12 \times 1.75$  thread will have a major diameter of 12 mm and a pitch of 1.75 mm.

The terms used when discussing threads and threading are shown below.

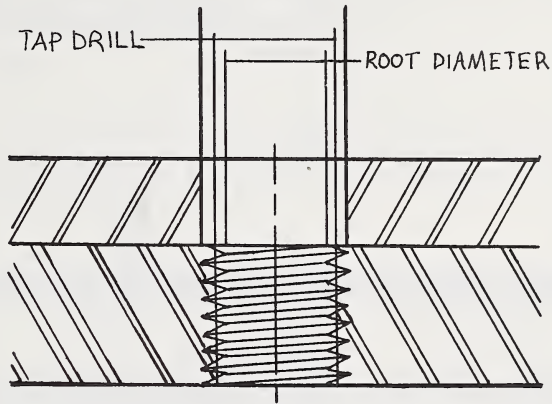


The major diameter is the diameter of the bolt measured across the peaks of the thread.

The minor diameter (also called root diameter) is the diameter of the bolt measured across the roots of the thread.

The crest refers to the top or tip of the thread while the root refers to the bottom of the thread. Thread angle on all "V" threads is  $60^\circ$ .

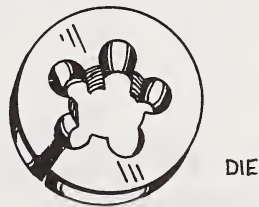
When cutting internal threads the drill size is selected from a tap drill chart. The size of the drill is similar to the root diameter of the thread. The threads will be cut outward from the hole and the peak of the thread will be equal to the major diameter.



Cutting oil must be used when cutting threads because it helps produce a better thread. There is less tearing away of portions of the thread. Also cutting oil extends the life of thread cutting tools. Only a small amount of thread cutting oil is required. It can be applied using a standard oil can.

The tap must be started straight. A tap can be turned into the work from one to one and a half turns. Then back the tap up one half turn to break the chip. Repeat this procedure until the tap reaches the desired depth. If a tap turns hard, back it up more often and use slightly more cutting oil. Do not apply excessive force or the tap may be broken.

**(b) Die**

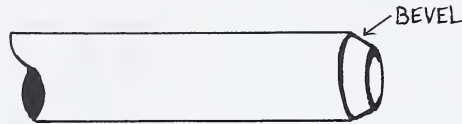


A die is held in a diestock.



A die is used to cut external threads onto a round piece of metal. The material diameter should be same size as the major diameter of the thread. For example, a  $10 \times 1.5$  mm thread will be cut on a 10 mm diameter rod and have a pitch of 1.5 mm. Dies are available for all standard size threads.

The end of the rod should be beveled slightly in order to aid in getting the die started.

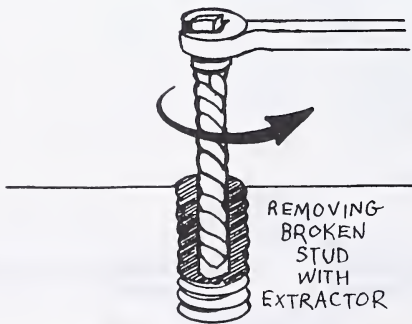


Once started the die should be turned two turns forward, then one turn back to clean the chips from the thread.

## 12. Stud and Bolt Extractors



When a stud or bolt breaks off below surface level, a stud extractor is needed to remove it. A stud extractor is basically a hardened tapered rod with coarse sharp left hand spirals. It has a square top for turning using an open end wrench.



To use the extractor, a hole is drilled in the centre of the stud. Stud extractor kits will give the size of drill to use for each extractor size. Turn the extractor counterclockwise into the hole. Apply pressure on the wrench and turn the stud out. Be careful not to apply too much pressure as it is possible to break off the extractor in the hole. This would further complicate the job of removing a broken stud.

## MEASURING INSTRUMENTS

Most overhaul jobs on vehicles involve checking sizes, clearances, and adjustments. Inaccurate measurements can greatly affect the operation and performance of a vehicle. Thus great care should be exercised when making all measurements.

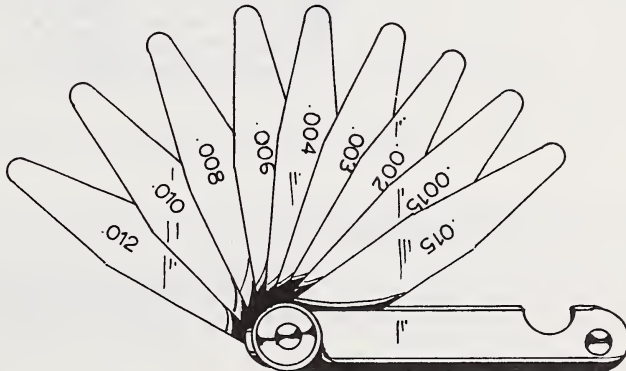
### 1. Steel Scales or Rules

The steel rule is the simplest of the measuring tools discussed in this lesson. It can be used for general measurements and also to check for warpage of parts. It is considered accurate to within  $\frac{1}{2}$  millimetre (or  $\frac{1}{64}$  inch) of the actual size for measurements of length, depth, thickness, etc.



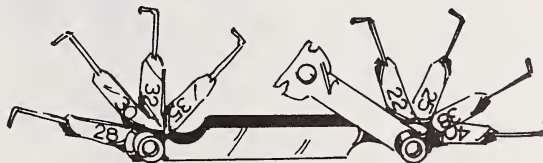
### 2. Feeler Gauge (Thickness Gauge)

The feeler gauge is ideal for measuring clearances, small gaps, and narrow slots. They are usually arranged in leaf form, each of which is marked for size.



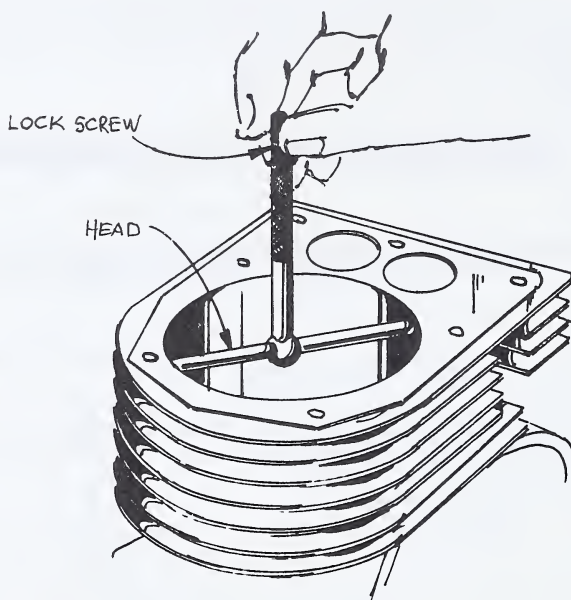
### 3. Wire Gauge

The wire gauge is a type of feeler gauge with wires of varying diameter instead of thin flat strips of steel as in the feeler gauge. The wire gauge is used for checking spark plug gap or ignition point gap.



#### 4. Telescoping Gauge

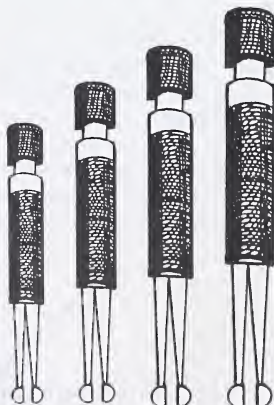
The telescoping gauge is used in conjunction with a micrometer for measuring inside bores of cylinder and other engine parts. The contact points compress and telescope within one another under spring tension. To obtain a measurement, insert the contacts into the bore and allow the contacts to expand. After the proper fitting has been made, lock the contacts into position. Finally, remove the gauge from the bore, place a micrometer caliper across the gauge, and take your reading from the micrometer.



Fitting a telescoping gauge into a cylinder bore.

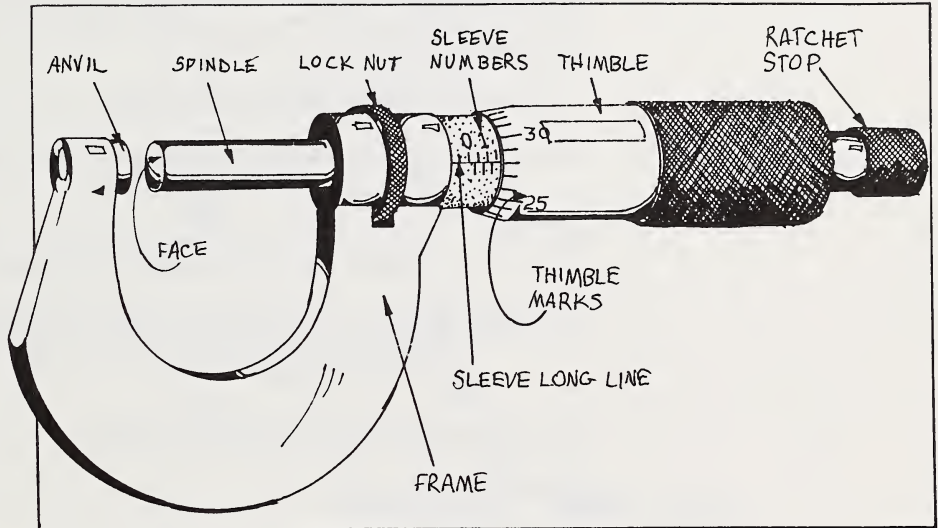
#### 5. Small Hole Gauge

The small hole gauge is used in a manner similar to the telescoping gauge. It is used for measuring inside diameters of small holes.

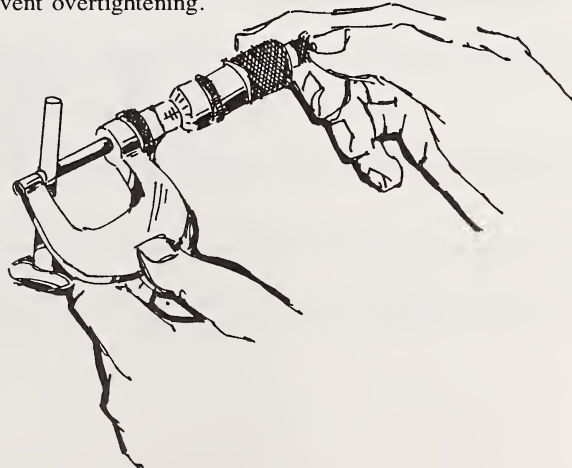


## 6. Micrometer

The micrometer is a precision measuring tool used to check diameters of crankshaft journals, wrist pins, shafts, etc. A micrometer is so accurate that it can be used to take measurements that are about one-thirtieth ( $1/30$ ) the thickness of a sheet of paper. Micrometers are made in many different styles and types (inside micrometers, outside micrometers, depth micrometers, 0-25 mm outside micrometers, 25-50 mm micrometers, etc.). Micrometers are available in metric as well as imperial units.



To make a measurement, the micrometer should be clamped to the object at the point you wish to measure. It is extremely important that you do not clamp the micrometer too tightly on the object. One should be able to slip the object in and out of the micrometer while giving the thimble a final adjustment. Damage to the micrometer will occur if the work is clamped too tightly. Good micrometers have a ratchet knob, which when used, will prevent overtightening.



**(a) Reading the Micrometer**

Above the sleeve long line (see diagram on page 27 of this lesson), the sleeve is divided into millimetres (from 0 to 25 mm). Below the sleeve long line each millimetre is subdivided into one half of a millimetre (0.5 mm). Therefore, two complete turns of the thimble changes the distance between the anvil and the spindle one millimetre.

The thimble is divided into 50 divisions with every fifth line numbered. The numbers occur in multiples of five (i.e. 0, 5 10, 15...50). Since one complete revolution of the thimble moves the spindle 0.5 mm, each division on the thimble equals  $1/50$  of 0.5 mm. In other words, each single division is equal to 0.01 mm, two divisions equal 0.02 mm, and so on.

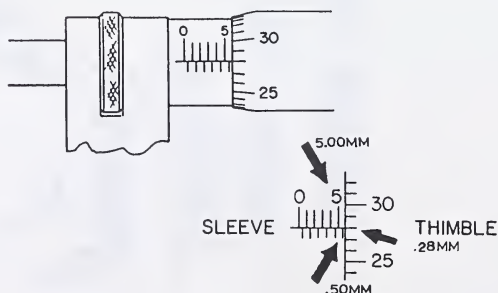
To read a micrometer follow these steps:

- Step One: Note the reading in millimetres visible on the sleeve. (Numbered lines above the sleeve long line.)
- Step Two: Add to this any 0.50 mm which may be visible on the sleeve. (Shorter lines below the sleeve long line.)
- Step Three: Add to the reading the number in hundredths of a millimetre indicated by the division on the thimble which coincides with the sleeve long line.

These steps are shown in the following example.

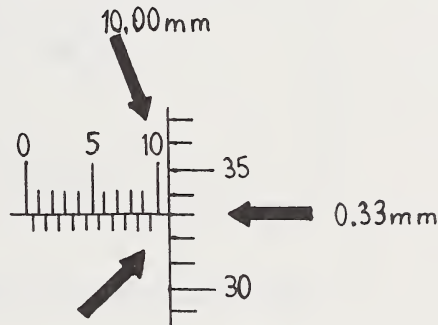
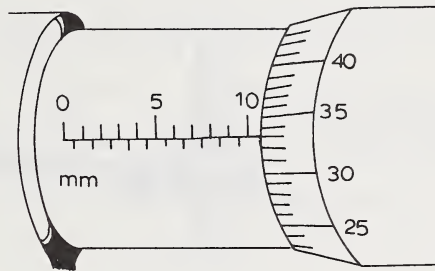
**Example 1**

Step 1	5.00	Sleeve reading in whole millimetres.
Step 2	0.50	Half millimetre
Step 3	0.28	Thimble reading in hundredths of a millimetre
	<u>5.78mm</u>	Add to get the reading



**Example 2**

Step 1	10.00	sleeve reading in whole millimetres
Step 2	—	No half millimetre line visible
Step 3	<u>0.33</u>	Thimble reading in hundredths of a millimetre
	10.33mm	

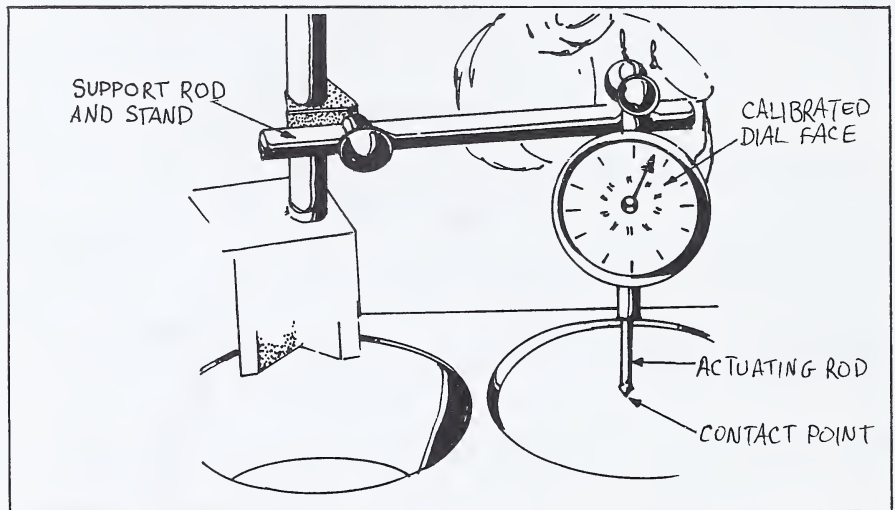
**(b) Caring for Micrometers**

- Do not place micrometers where they are subject to heat.
- Periodically check micrometers with a standard to ensure accuracy.
- Store micrometers in their cases or boxes.
- Clean a micrometer frequently with a clean cloth oiled with a few drops of machine oil.
- Be sure that the contact faces are clean before making a measurement.
- Avoid dropping a micrometer. If one is accidentally dropped have its accuracy checked using a standard.

## 7. Dial Indicator or Gauge

The dial indicator is used for checking and measuring end play in shafts, backlash between gears, valve lift, taper in cylinders, and determining piston top dead center.

The face of the dial indicator is calibrated in hundredths of a millimetre. The distance over which the indicator can be used vary with the type of instrument used. Since the indicator is used on various setups, swivels, adapters and mounting arms are supplied with each unit.

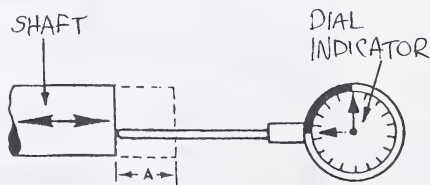


### Using the dial indicator to determine piston top dead center

When using a dial indicator, firmly mount the unit so that the actuating rod is parallel to the direction of movement to be measured.

Place the contact point against the work to be measured. Then push the indicator toward the work causing the needle to travel far enough around the dial so that movement of the work in either direction will result in needle deflection. Turn the dial face to line the zero (0) mark with the indicator needle.

The following diagram demonstrates the use of a dial indicator to measure end play (movement) of a shaft through a distance marked as A.



**8. Care and Maintenance of Tools**

- (a) Tools should be kept clean, orderly and close at hand.
- (b) Delicate measuring tools should be placed in protective cases or boxes.
- (c) Separate cutting tools (such as files, drills, chisels, etc.) from other tools to prevent damage to their cutting edges as well as damage to other tools.
- (d) Tools are subject to rusting. To avoid rust, lightly coat each tool with a rag containing a few drops of machine oil.
- (e) Place heavy tools in a location by themselves.
- (f) Keep cutting tools sharp.
- (g) Use all tools with care and follow all safety recommendations.

Complete the following Self-Correcting exercises and check the answers with those listed at the end of this lesson.

### SELF-CORRECTING EXERCISE 1

Which tool discussed in the lesson notes is best for each of the following jobs?

1. \_\_\_\_\_ pounding on a chisel
2. \_\_\_\_\_ removing a shaft without putting marks on it
3. \_\_\_\_\_ determining the amount of wear on a crankshaft
4. \_\_\_\_\_ checking a cylinder bore for wear
5. \_\_\_\_\_ checking the gap on spark plugs
6. \_\_\_\_\_ checking a cylinder head for warpage
7. \_\_\_\_\_ for cutting threads onto a rod
8. \_\_\_\_\_ accurate sizing of a drilled hole
9. \_\_\_\_\_ check a twist drill point for proper angle
10. \_\_\_\_\_ avoiding injury from a hammer striking your hand while using a chisel
11. \_\_\_\_\_ removing the mushroomed top from a chisel
12. \_\_\_\_\_ quick removal of metal by hand
13. \_\_\_\_\_ tightening a bolt to 100 newton-metres
14. \_\_\_\_\_ speedy removal of a bolt
15. \_\_\_\_\_ removal of a gas line fitting from the carburetor on a vehicle
16. \_\_\_\_\_ cutting cotter pins to the correct length
17. \_\_\_\_\_ making holes in metal brackets

**SELF-CORRECTING EXERCISE 2**

In the multiple-choice questions listed below choose the letter of the best answer and place it in the space to the left of the question.

- \_\_\_\_\_ 1. Why are high carbon steel drills not commonly used even though they are inexpensive?
- (a) They dull quickly.
  - (b) They wander off the mark more easily.
  - (c) They will only work on a drill press.
  - (d) They produce rougher finishes inside of holes.
- \_\_\_\_\_ 2. What is the likely result of having unequal drill point angles on a twist drill?
- (a) The hole will move off to one side.
  - (b) Only one lip will cut and the hole will be oversized.
  - (c) There will be no noticeable change in results.
  - (d) The drill will not cut into the work.
- \_\_\_\_\_ 3. What size of a hole would have to be drilled in order to cut  $12 \times 1.75$  mm threads?
- (a) 8.5 mm
  - (b) 10.25 mm
  - (c) 12.00 mm
  - (d) 15.00 mm
- \_\_\_\_\_ 4. Why is it best to bevel the end of a rod before threading it?
- (a) Smoother threads can be made when the end is bevelled.
  - (b) This will make it easier for a tap to be started correctly.
  - (c) This will make it easier for a die to be started correctly.
  - (d) Bevelling will make no noticeable difference in how the thread starts.
- \_\_\_\_\_ 5. Why is a stud remover not likely to work to remove a stud that is rusted and seized in place and was broken while an attempt was made to remove it?
- (a) The stud remover may break.
  - (b) The rust will make it difficult to drill a hole in the stud.
  - (c) Rusty studs will usually break at an angle, making it hard to drill a hole in them.
  - (d) A socket stud wrench would work better.
- \_\_\_\_\_ 6. What is another method of removing the broken stud described in question 5?
- (a) Arc weld a nut to the top of the broken stud.
  - (b) Spray penetrating oil on the rusted stud and allow it to soak in before turning on the stud remover.
  - (c) Both of the above methods could be used.
  - (d) If a stud remover will not work, the stud cannot be removed.



Complete the following exercises and send them in for correction.

### EXERCISE 1

Write out complete answers for each of the following questions.

1. Why is it important that heavy blows not be employed while using a brass hammer?

---

---

2. Why is it important to always strike a chisel head squarely with a hammer?

---

---

3. Why are layout marks always centre punched before drilling a hole?

---

---

4. Why should files never be stored in a damp location?

(a) 

---

---

- (b) What does this do to the file teeth?

---

---

5. Why is it important that a file not be used unless it has a handle on it?

---

---

6. Why do some heavy duty screwdrivers have a square shank on them?

---

---

7. Why do longer screwdrivers tend to stay in the screw slot better than short ones?

---

---

---

8. What is the main advantage of a 6-point socket over a 12-point socket?

---

---

9. What is the main advantage of a 12-point socket over a 6-point socket?

---

---

10. Why is a socket flex handle sometimes used even though a ratchet will do much the same type of work?

---

---

11. What special tool is used to remove and reinstall studs? \_\_\_\_\_

12. Why is it dangerous to push on a wrench?

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13. Why is a box end wrench considered better than an open end wrench for the final tightening of a bolt or nut?

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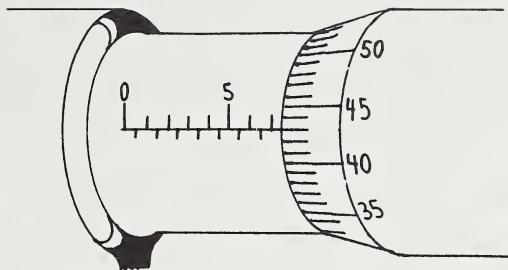
14. Why are pliers not used to tighten bolts or other fasteners?

---

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**EXERCISE 2**

1.



What is the reading on the micrometer shown above? \_\_\_\_\_

2. Explain how to set up a dial indicator to check the end play of a shaft.

---

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---

---

3. Why is it important to store tools such as files, drills, chisels, etc. separate from each other?

---

---

4. Why is it important not to overtighten the micrometer when taking a measurement?

---

---

5. How can overtightening be avoided when using a micrometer?

---

---

**ANSWERS TO SELF-CORRECTING EXERCISES****Self-Correcting Exercise 1**

- |                                     |   |
|-------------------------------------|---|
| 1. ball peen hammer (page 1)        | 10. chisel holder (page 3)  |
| 2. brass or plastic hammer (page 1) | 11. bench grinder (page 2 of this lesson and page 20 of Lesson 4) |
| 3. micrometer (page 27)             | 12. double cut file (pages 4-5)                                   |
| 4. telescoping guage (page 26)      | 13. torque wrench (page 13)                                       |
| 5. wire gauge (page 25)             | 14. socket speed handle (page 12)                                 |
| 6. steel rule (page 25)             | 15. flare nut wrench (page 15)                                    |
| 7. die (page 23)                    | 16. diagonal cutting pliers (page 16)                             |
| 8. reamer (page 20)                 | 17. twist drill (page 17)   |
| 9. drill point guage (page 19)      |   |

**Self-Correcting Exercise 2**

- |                |                          |
|----------------|--------------------------|
| 1. a (page 17) | 4. c (page 24)           |
| 2. b (page 19) | 5. a (page 24)           |
| 3. b (page 22) | 6. c (no reference page) |

**END OF LESSON 5**

## LESSON RECORD FORM

1746 Mechanics 12  
Module 1

### FOR STUDENT USE ONLY

Date Lesson Submitted

(If label is missing  
or incorrect)

File Number

Time Spent on Lesson

Lesson Number \_\_\_\_\_

### Student's Questions and Comments

Apply Lesson Label Here

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Lesson Grading: \_\_\_\_\_

Additional Grading

E/R/P Code: \_\_\_\_\_

Mark: \_\_\_\_\_

Graded by: \_\_\_\_\_

Assignment Code: \_\_\_\_\_

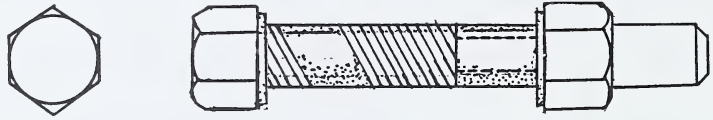
Date Lesson Received:

Lesson Recorded \_\_\_\_\_

Teacher's Comments:

Correspondence Teacher

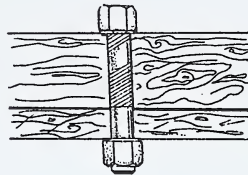
## 2. Machine Bolts



Machine bolts are used to assemble larger parts that do not require close tolerances. They are manufactured with hexagonal heads and are usually furnished with nuts.

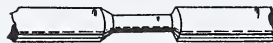
### (a) Bolts

Machine bolts are available in diameters ranging from 12.5 mm to 75 mm and lengths from 12.5 mm to 750 mm.



Bolts are available in various degrees of hardness and strength.

- (i) In the imperial measurement system bolts are grouped into grades. Grades 0, 1 and 2 bolts are the softest and have the lowest tensile strength. Tensile strength is the amount of pull an object will withstand before breaking. In the imperial measurement system this is measured in pounds of pull per square inch of area across the sample.



Bar of steel to be tested for tensile strength.

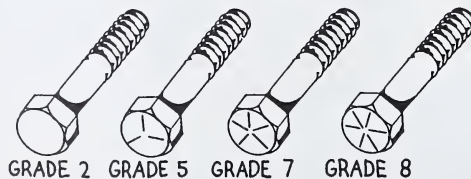


Heavy tension applied to bar.



Increased pull finally snaps the bar. The tensile strength is the maximum pull (measured in pounds per square inch) required to break the bar.

Grade 8 bolts are the hardest bolts and have the greatest tensile strength. The grade markings are recorded in the form of lines on the bolt head. Note that there is always two lines less than the actual grade.

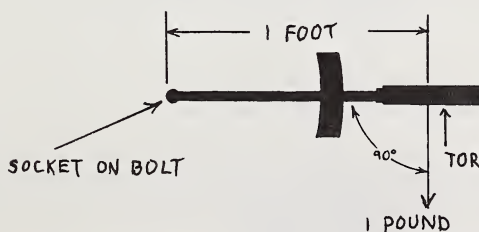


- (ii) In the metric system a straight number system is used to designate grades. The higher the number, the greater the tensile strength.

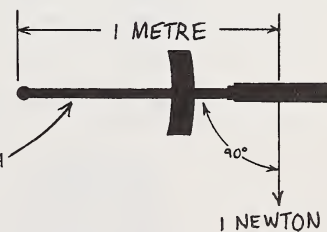


SAE and ISO Grade Markings for Steel Bolts				
SAE Grade Marking	ISO Grade Marking	Material	Tensile Strength SAE	Tensile Strength ISO
 Grade 1 or 2	 5.8	Low carbon steel	55 000 to 69 000 psi	440 MPa
 Grade 5	 8.8	Medium carbon steel Quenched and Tempered	120 000 psi	725 MPa
 Grade 8	 10.9	Medium carbon alloy steel Quenched and tempered	150 000 psi	1035 MPa

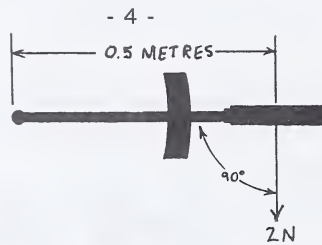
Tensile strength is important to the mechanic as it determines how tight he can torque bolts without fear of breakage. Torque is the amount of twisting force applied to a bolt or nut.



The torque on the bolt shown above would be 1 foot pound.



Torque on the bolt shown above would be 1 Newton metre or 1 N•m. (The length of this torque wrench is longer than normal. The same torque could be applied as shown in the next example.)



The torque as shown here would be  $1 \text{ N}\cdot\text{m}$ , (calculated by multiplying  $0.5 \text{ m} \times 2 \text{ N}$ ).

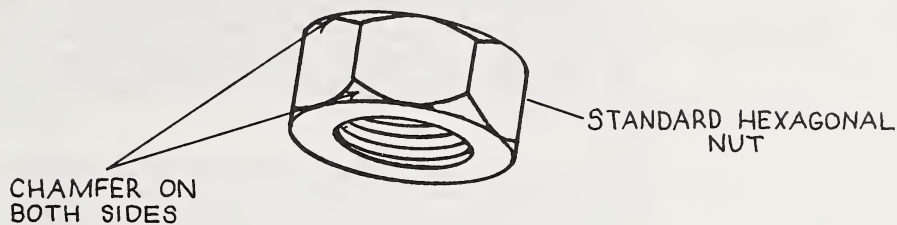
From the above examples, it can be seen that torque can be calculated by multiplying the length of the lever arm (torque wrench length) by the force applied to the end of the torque wrench.

Below is a torque chart which can be used for most sizes and grades of cap screws threaded into steel or cast iron.

Capscrew Body Size Inches - Thread	SAE Grade 1 or 2 (Used Infrequently)		SAE Grade 5 (Used Frequently)		SAE Grade 6 or 7 (Used at Times)		SAE Grade 8 (Used Frequently)	
	Torque		Torque		Torque		Torque	
	150 Marking 5.8		150 Marking 8.8		150 Marking 9.8		150 Marking 10.9	
	Ft-Lb	N·m	Ft-Lb	N·m	Ft-Lb	N·m	Ft-Lb	N·m
1/4-20	5	6.8	8	10.8	10	13.6	12	16.3
	-28	6	10	13.56			14	19.0
5/16-18	11	14.9	17	23.04	19	25.8	24	32.5
	-24	13	19	25.8			27	36.6
3/8-16	18	24.4	31	42.0	34	46.1	44	59.7
	-24	20	35	47.5			49	66.4
7/16-14	28	38.0	49	66.4	55	74.6	70	94.9
	-20	30	55	74.6			78	105.8
1/2-13	39	52.8	75	101.7	85	115.2	105	142.4
	-20	41	85	115.2			120	162.7
9/16-12	51	69.1	110	149.1	120	162.7	155	210.1
	-18	55	120	162.7			170	230.5
5/8-11	83	112.5	150	203.4	167	226.4	210	284.7
	-18	95	170	230.5			240	325.4
3/4-10	105	142.4	270	366.1	280	379.6	375	508.4
	-16	115	295	400.0			420	569.4
7/8-9	160	216.9	395	535.5	440	596.6	605	820.3
	-14	175	435	589.8			675	915.2
1-8	235	318.6	590	799.9	660	894.8	910	1233.8
	-14	250	660	894.8			990	1342.2

The torque should be reduced by 10% if the threads are oiled. If plated cap screws are used, torque should be reduced even more. Always follow the manufacturer's torque specifications when assembling parts.

- (b) Nuts have an external hexagonal shape and have threads cut into a hole drilled through them.



The standard hexagonal nut is usually supplied with bolts. Most standard hexagonal nuts are chamfered (beveled) on both sides so they can be installed either side down.

Various other styles of nuts are available.



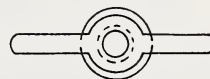
JAM  
NUT



CASTELLATED  
NUT

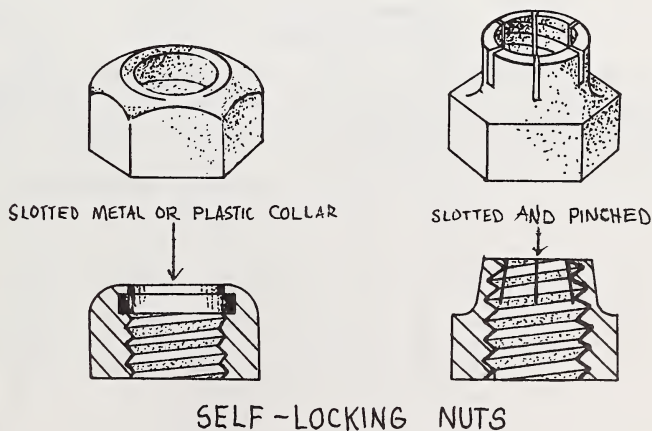


ACORN  
NUT



WING  
NUT

The jam nut is tightened against a standard hexagonal nut to lock it in place. Castellated nuts are slotted across the flats to receive a cotter pin after the nut has been tightened. The cotter pin prevents the nut from turning loose. Acorn nuts are chosen when appearance is of importance. Wing nuts are used when frequent adjustment or removal is necessary. They are only suitable when finger tightening is sufficient.



Some nuts are designed to be self-locking. This is done by creating friction between the threads of the nut and the bolt. One style uses a soft metal or plastic collar. As the bolt threads pass through the nut, they must force their way through the collar. This jams the collar material tightly into the threads of the bolt, thus locking the nut in place. The other style of nut uses the fact that the bolt must spread the pinched section of the nut as it passes through. This produces a locking action.

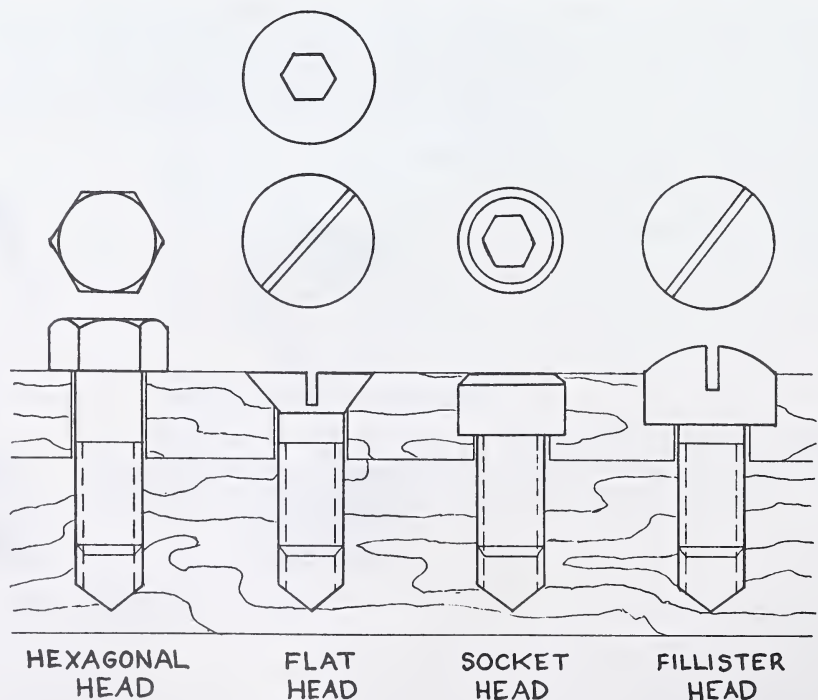
Standard hexagonal nuts can be locked in place chemically with a liquid lock. Chemical locks are usually in the liquid form when purchased. They are applied to the threads of a bolt and fill the spaces between the threads. Once the nut is tight the chemical hardens and locks the bolt in place. Vibration will not loosen the bolt.

### 3. Cap Screws

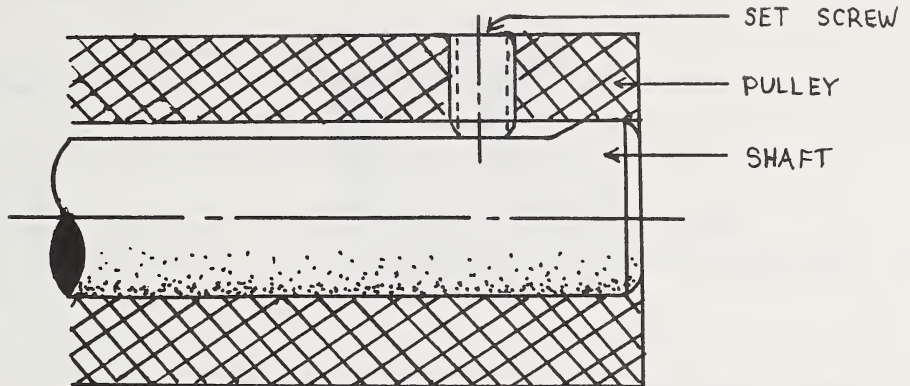
Cap screws are kept to much closer tolerances in their manufacture. They are also given a machined surface (not just stamped as is the case with machine bolts) on the underside of the head.

Cap screws are used in assemblies requiring higher quality and a more finished appearance than those using machine bolts. Their function is much the same as a machine bolt, however, the cap screw passes through a clearance hole in one of the pieces of material and screws into a threaded hole in the other piece of material. Nuts are not used in assemblies involving cap screws. In fact cap screws are mainly used in locations where it is not possible to place a nut on the threaded end.

Cap screws are stocked in both coarse and fine threads. Cap screw diameters range from 6 mm to 50 mm and they are available in lengths ranging from 10 mm to 250 mm.

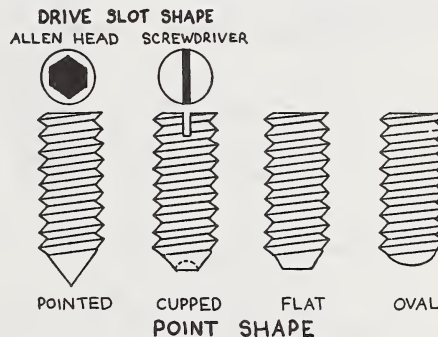


#### 4. Setscrews



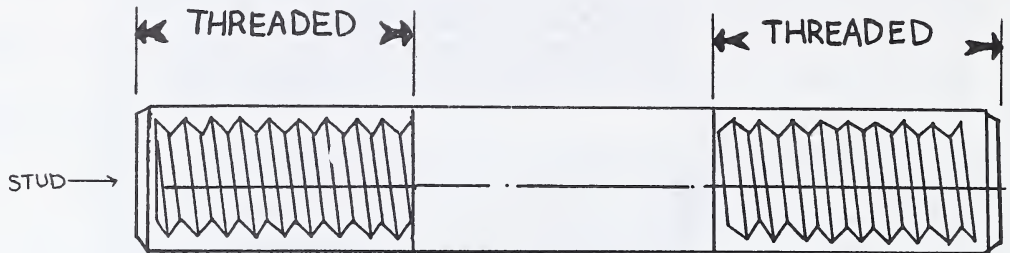
The major uses for setscrews are to prevent pulleys from slipping on shafts and to hold collars in place on shafts. Setscrews are usually made from heat-treated steel in order to make them very hard. This is so they can be tightened very tight.

Setscrews are available in two styles. The headed style has a separate head formed on it. This head is usually square and can be tightened using an open end wrench. The headless style has no head on it. They require an Allen wrench or a slot screwdriver (depending on the shape of the drive slot) in order to be tightened. The headless setscrews are used in areas where there is a danger of clothing catching on the setscrew. Setscrews have a variety of points on them. Some of the point styles are shown below.

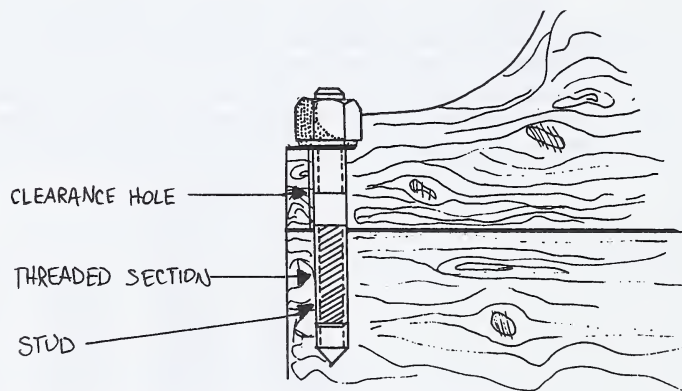


The pointed setscrew is used for setting machine parts permanently on the shaft. The cupped setscrew helps prevent movement of the part yet does not cause excessive shaft scoring. Flat setscrews make frequent adjustments possible without leaving any marks on the shaft. Oval setscrew tips are usually used when there is a flat spot on the shaft for the setscrew to set on.

### 5. Stud bolts

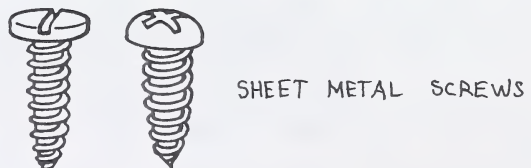


Stud bolts are usually made of low carbon steel and are threaded on both ends. One end is threaded into a tapped hole. The part to be attached is then placed over the stud and a nut is screwed on to hold the two pieces together. Some automobile engine exhaust manifolds employ the use of studs. Studs allow parts to be guided into proper position during assembly and then allow tightening into place.



### 6. Sheet metal screws and thread cutting screws

Sheet metal screws press or form a thread as they are driven. This eliminates a costly tapping operation. They are usually used to fasten parts to thin sheet metal.



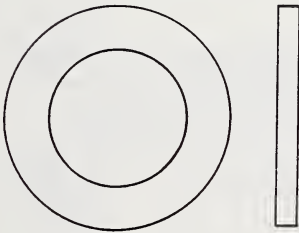
Thread cutting screws differ from sheet metal screws in that the tip of the screw is shaped like a tap and actually cuts its own thread as it is driven into the metal. Thread cutting screws are hardened so they keep their shape during installation. These screws are used to fasten parts to heavier sheet metal or to castings made of non-ferrous metals (metals other than iron or steel).



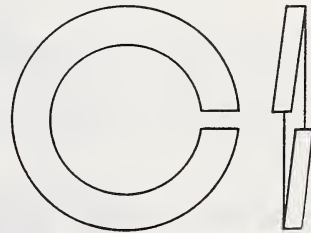
Sometimes both of these screw types are referred to as self-tapping screws.

## 7. Washers

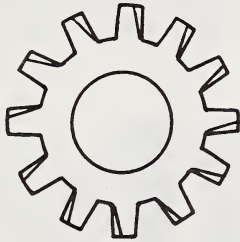
Washers are available in two styles — plain flat washers and lock washers.



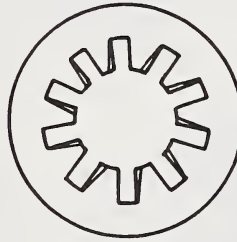
plain flat washer



plain lock washer



external lock  
washer



internal  
lock  
washer

- Courtesy of John Deere Ltd.



internal-external  
lock washer

Plain flat washers are used to distribute the load over a larger area and to prevent marring of the surface surrounding the bolt hole.

Lock washers prevent a nut or bolt from loosening under vibration. The plain lock washer is being replaced by the internal or external lock washers since the plain lock washer badly mars the surface around the hole. Sometimes a plain flat washer is placed between the lock washer and the casting.

### 8. Snap Rings (Retaining Rings)

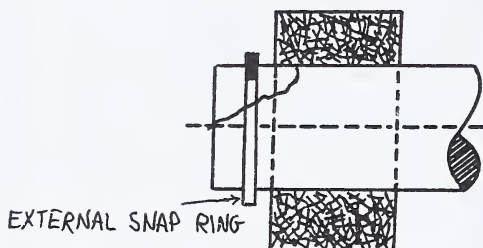


EXTERNAL SNAP RING

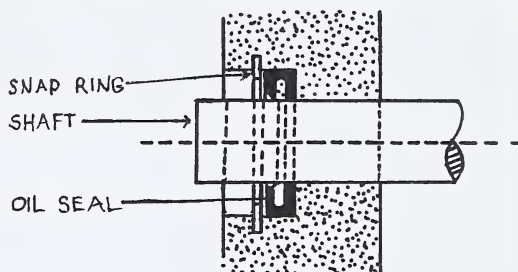


INTERNAL SNAP RING

Snap rings allow a shaft to rotate freely but prevents it from moving endwise out of place. Snap rings are also used to prevent bearings and other components from moving sideways out of place.

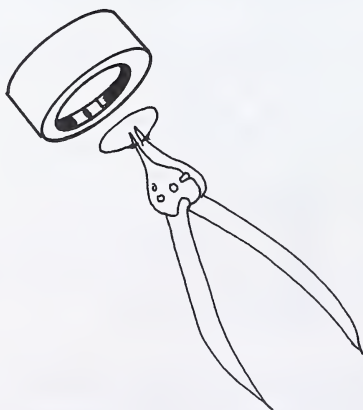


USE OF EXTERNAL SNAP RING TO RETAIN  
SHAFT IN THE PROPER LOCATION

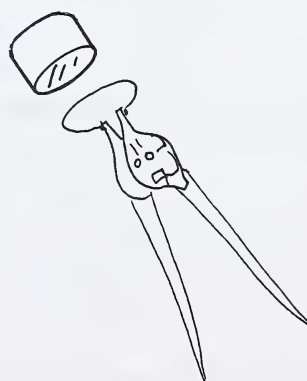


USE OF INTERNAL SNAP RING  
TO RETAIN AN OIL SEAL

Special snap ring pliers are required to install snap rings. These pliers have small circular jaws which fit the holes in the ends of the snap ring. Two styles of snap ring pliers are required as shown below.

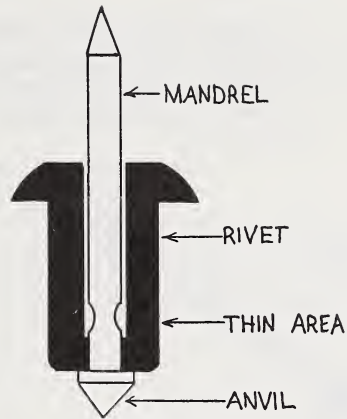


INTERNAL SNAP RING PLIERS

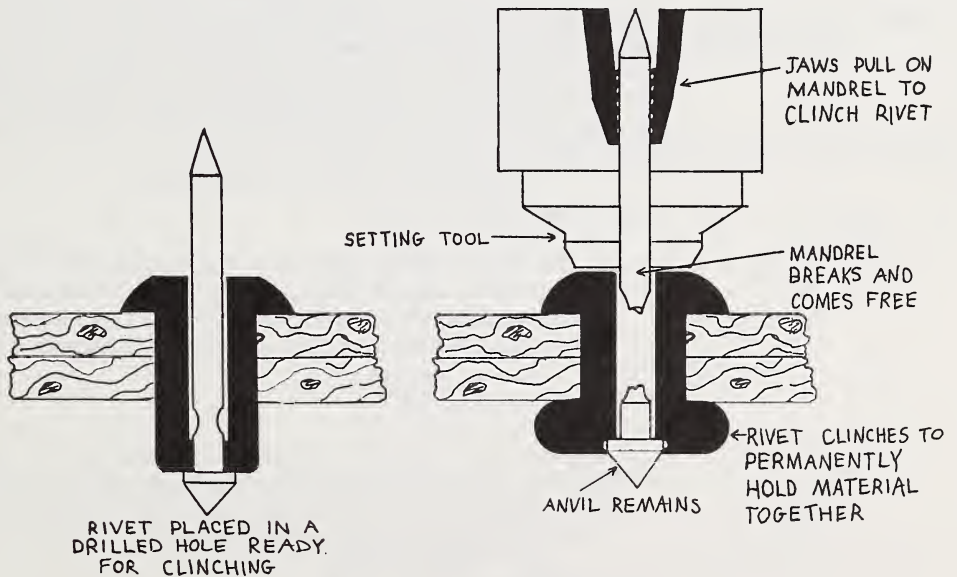


EXTERNAL SNAP RING PLIERS

### 9. Pop Rivets



Pop rivets are tubular rivets with a thin stem (mandrel) running through them. On one end of the mandrel is an anvil. The pop rivet is inserted into a drilled hole, a special tool is attached to the mandrel which applies pressure to pull the anvil into the rivet. When enough pressure has been applied the mandrel breaks at the thinned area.

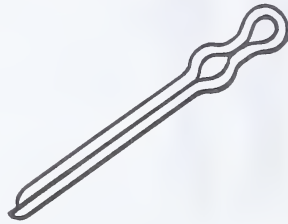


One of the main advantages of pop rivets is that they can be set from one side only. This is a great advantage over conventional rivets which must be supported from the back side as they are clinched with a hammer or rivet set.

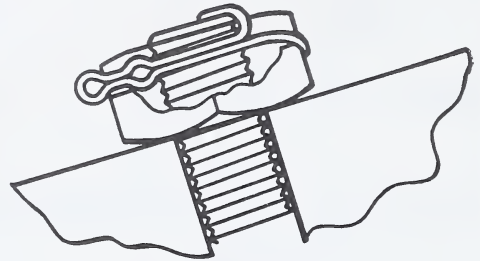
Pop rivets are used to permanently fasten lighter materials together quickly and easily. In industry air operated pop rivet tools speed assembly of many projects.

### 10. Cotter Pins

Cotter pins are used to prevent slotted and castle nuts from working loose. Bolts or spindles which require cotter pins will have a hole drilled through them big enough to accept the cotter pin. After the nut is installed and tightened, the slots in the nut are lined up with the pin hole in the bolt. The cotter pin is installed and the two legs bent sideways.



COTTER PIN BEFORE  
INSTALLATION



COTTER PIN AFTER  
INSTALLATION

- Courtesy of John Deere Ltd.

### 11. Removing 'Frozen' Bolts, Setscrews and Cap Screws

Salt and moisture have a corrosive effect on threaded fasteners. With the passage of time fasteners may corrode badly and become difficult to remove. If excessive force is applied, the fastener may be damaged or broken off. One of the secrets of a successful mechanic is the ability to recognize the maximum amount of force that can be applied to a fastener without fear of the fastener breaking. If the fastener has not loosened at this time, then the mechanic will resort to one of the following methods to help free the fastener.

#### (a) Use an impact wrench

The shock produced by an air or electric impact wrench will sometimes free fasteners while a steady force applied by a wrench would break the fastener. Special striking wrenches are produced which can be hit with a hammer to free stubborn nuts or bolts. Hitting a standard wrench with a hammer is not recommended.

#### (b) Use Penetrating Oil

Sometimes difficult to remove fasteners can be freed using penetrating oil. This is a special oil which will flow into tight places and dissolve some of the rust. For stubborn nuts or bolts apply penetrating oil several times at approximately 5 minute intervals in order to allow the oil to soak into the threads.

#### (c) Apply Heat

Some stubborn nuts can be removed by heating them. By applying heat to a nut, it will expand slightly on the bolt. This slight expansion may be enough to free the nut. Care must be taken to neither damage other parts nor create a fire hazard.

## 12. Removing Broken Fasteners

When care is taken while removing fasteners, there is less chance of breakage. However it seems at one time or other studs or cap screws are broken. Several methods can be attempted to remove them. The choice of methods will depend partly on experience and partly on exactly where the stud breaks.

### (a) Broken stud projects above the work

If a large enough portion of the stud projects above the work, it may be gripped with a pipe wrench or vise-grip pliers and turned out. Where the protruding portion of the stud is not long enough to grip as explained above, then flat surfaces may be filed on the stud to take a wrench. Also a slot could be cut to allow the use of a screwdriver.



BROKEN STUD FILED TO  
ACCEPT AN OPEN  
END WRENCH

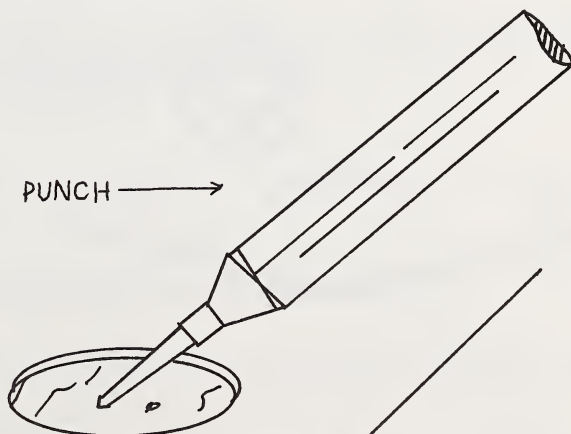


BROKEN END OF STUD SLOTTED  
TO ALLOW THE USE  
OF A SCREWDRIVER

Another alternative is to weld a nut over the broken stud with an arc welder. When using this method, be careful of fire and heat damage to parts.

### (b) End of stud slightly below work surface

If the stud is broken off at or slightly below the surface of the work, try using a sharp pointed punch to free the stud.



USING A PUNCH TO FREE  
A BROKEN STUD

(c) **Using a stud extractor**

The procedure to follow when using a stud extractor is given in Lesson 5.

(d) **Alternate method**

If all of the above methods fail, select the proper size of tap drill. Start in the exact center of the stud and drill down through the stud. Carefully tap out the hole. If the procedure is properly done, stud threads will be removed leaving the threads in the hole undamaged.

When using the methods discussed in sections (a), (b) and (c) above, the "frozen" stud will have to be freed before it can be successfully removed. Section 11 supplies details on freeing frozen fasteners. Heat cannot be used while stud extractors are in the hole as heat will cause softening of the stud extractor. If the hardness is removed from a stud extractor, the sharp corners will round. This ruins the stud extractor as it will not grip a stud.

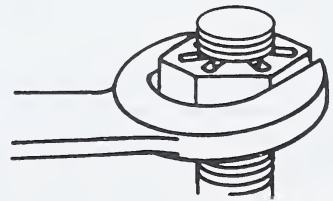
### 13. Restoring Damaged Threads

Rusted bolts may be difficult to reuse since the rust increases the amount of force required to tighten the fastener properly. Damage to threads caused by tools or other metal objects can also increase the amount of force required to tighten fasteners.

These rusted or damaged threads can be cleaned or restored using a thread restoring die. A rethreading die, as they are called, works better for this job than an ordinary die. The reason for this is the rethreading die has narrower chip slots in it and therefore is more likely to start straight on the bolt threads. If the die does not start straight, cross threading is likely to result which will ruin the bolt.



RETHREADING DIE

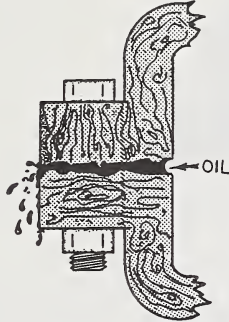


*-Courtesy of John Deere Ltd.*

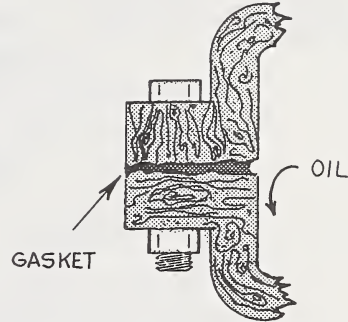
Nuts are very seldom rethreaded since they are inexpensive to replace.

## GASKETS

A gasket is a piece of material placed between two or more parts so that when the parts are pulled together the joint will not leak. The gasket will fill any irregularities such as warped spots, scratches, dents, etc.



Most surfaces have small irregularities which do not seal well



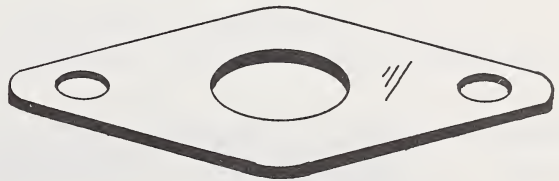
Gasket material fills irregularities and stops leak

Gaskets may be constructed of paper, felt, cork, rubber, asbestos, copper, aluminum, or steel. Sometimes the entire gasket is made from one of these materials and sometimes two or more of these materials will be used in combination. Gasket materials must compress somewhat in order to seal. They must not, however, compress beyond a specified limit or they may begin to leak.

Gasket materials are chosen based on the following criteria: temperature and temperature extremes, type of fluid to be confined, corrosiveness of the fluid, pressure of confined fluid, smoothness of mating surfaces, fastener tension, etc.

Some gaskets such as the thermostat housing gaskets are of very simple construction. It is made from medium thickness, chemically treated paper.

THERMOSTAT GASKET

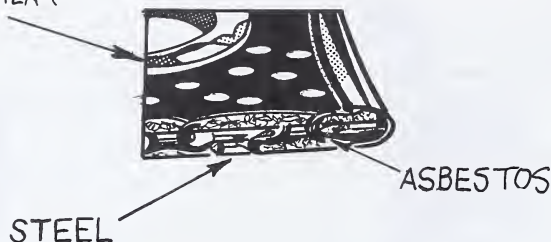


This type of gasket serves well in locations where the pressure is low and corrosion problems are only mild.

Gaskets such as a manifold to exhaust gasket become more complex. The pressure on the gasket flanges is greater while corrosive flames and high temperatures attempt to destroy the gasket. In this type of gasket, asbestos and steel materials are used.

Head gaskets are the most complex gaskets. They must withstand considerable pressure plus very high combustion temperatures and yet the gasket must seal against oil and coolant.

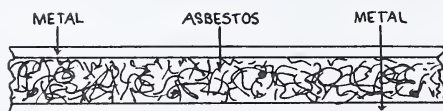
REINFORCEMENT AROUND CYLINDER OPENING  
SO SEALING PRESSURE WILL BE INCREASED  
IN THIS AREA TO PREVENT  
LEAKAGE



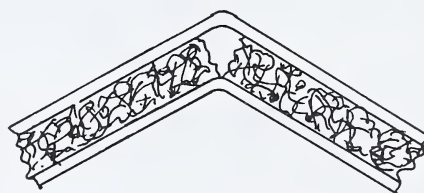
Gaskets should never be reused. Once a gasket has been in use for a period of time, it will lose a great deal of resiliency. When removed, it will not return to its original thickness. When reused, it will not compress and seal properly. Without a proper seal, a leak is sure to occur.

Before installing a new gasket, the mating surfaces should be thoroughly inspected. Surfaces which are nicked, dented, or have pieces of old gasket on them will not seal properly. These surfaces will have to be repaired or cleaned to insure there will be no leaks.

New gaskets should be checked for condition. Head gaskets which have been folded should never be used.



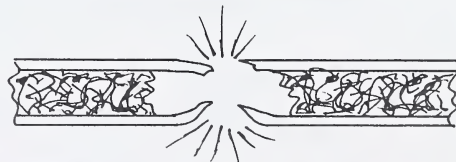
An example of a head gasket



An example of a head gasket that has been creased

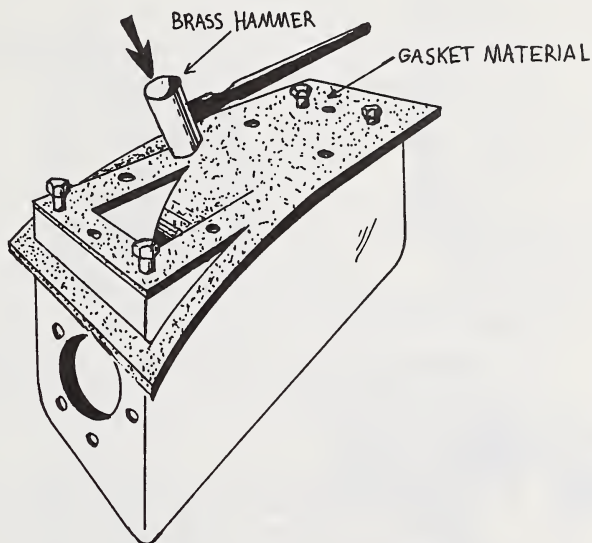


Head gasket showing a void in the asbestos after straightening



The head gasket may leak or "blow" if placed in service.

Simple paper gaskets can easily be cut from sheets of gasket material. The sheet of gasket material can be laid out and then cut with scissors. Also a gasket can be cut by placing the gasket material over the part, then tapping along the edges of the casting with a brass hammer. Holes can be cut by tapping around the edges of the hole with a ball peen hammer.



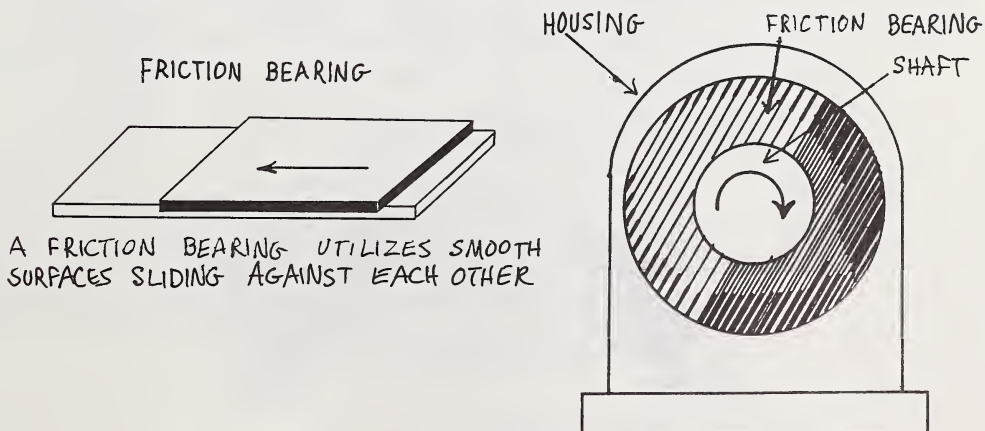
An example of cutting a gasket from sheet stock using a brass hammer.

## BEARINGS

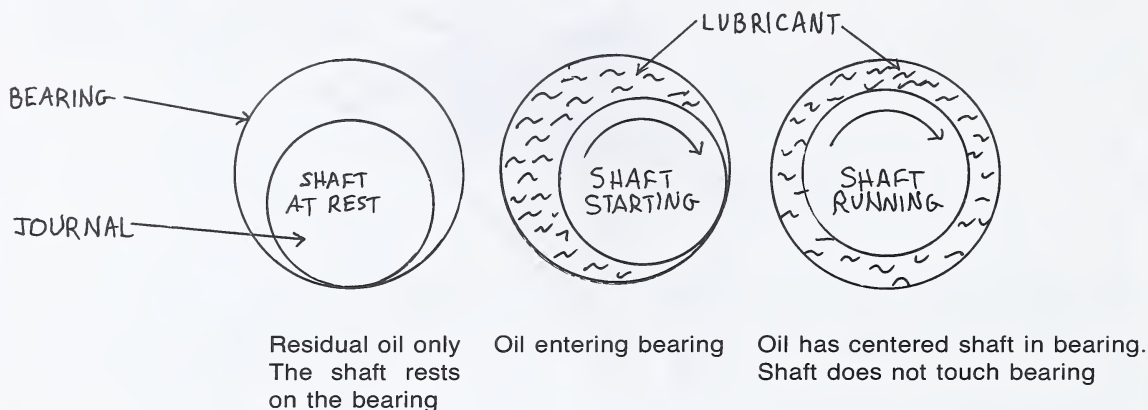
Bearings reduce the friction between rotating parts. There are two basic classifications of bearings, friction and antifriction bearings.

### 1. Friction Bearings

Friction bearings utilize sliding contact between two surfaces. Sliding contact produces friction.



Although friction bearings do have more friction than other types of bearings, means have been taken to reduce friction as much as possible. Oil is forced between the shaft and the bearing so the shaft actually rides on a film of oil. With this proper oiling the friction will be between the oil molecules within the oil film.

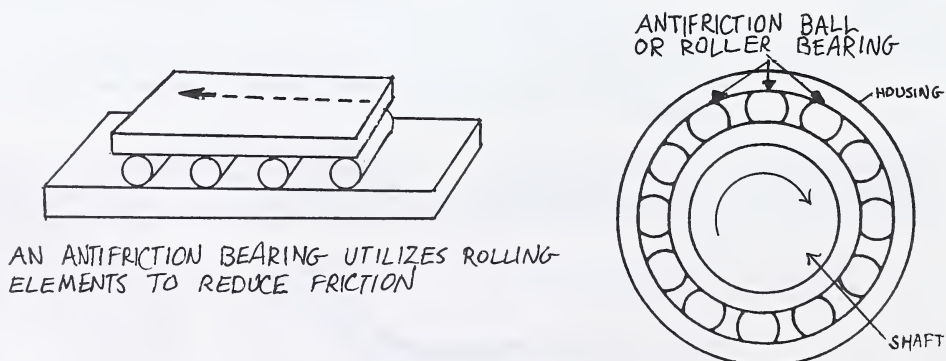


Friction bearings are used extensively in automobile engines. Camshaft, crankshaft, and connecting rod bearings are friction bearings. They have a larger load area for their size and hence can take considerably greater loads than other bearing styles. They are also less expensive to manufacture and to service.

One piece friction bearings are often referred to as bushings. Terms like bearing shells or bearing inserts refer to multi-piece friction bearings.

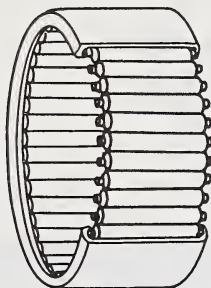
## 2. Antifriction bearings

Antifriction bearings use rolling elements such as balls or rollers to reduce friction.

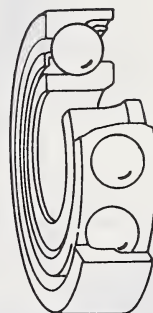


Notice in the above diagrams that there is considerably less load contact area on this style of bearing than on a comparably sized friction bearing. Although the friction may be less in this bearing type, they will not carry the same amount of load that a comparable sized friction bearing would. Antifriction bearings are used in transmissions, differentials, power steering systems, etc.

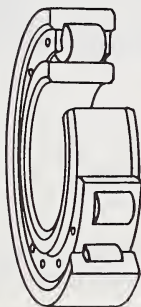
There are many types of antifriction bearings in use, some of which are shown below.



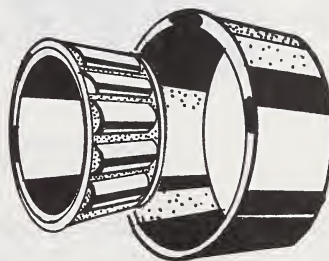
Needle bearing



Ball bearing



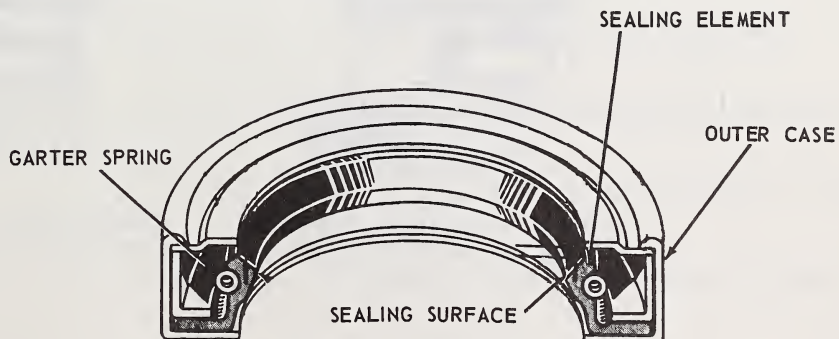
Roller bearing



Tapered roller bearing

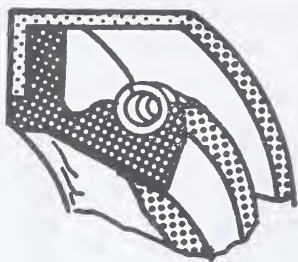
## SEALS

Oil or grease seals are used between a shaft and a housing. An oil seal can be used to perform tasks such as confining fluids, preventing entry of foreign materials or separating two different fluids. Some seals may have to withstand high pressures. Most oil seals contain three basic parts. These parts are a metal case, a sealing element, and a small spring. Oil seal lips can be made from synthetic rubber, leather, or felt.

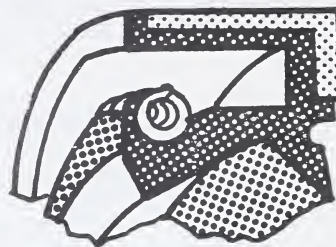


- Courtesy of John Deere Ltd.

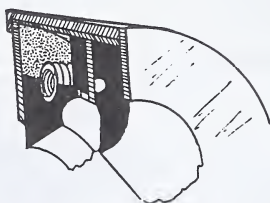
Oil seals have several styles of sealing lips.



Single sealing lip  
Fluid is contained from this side only

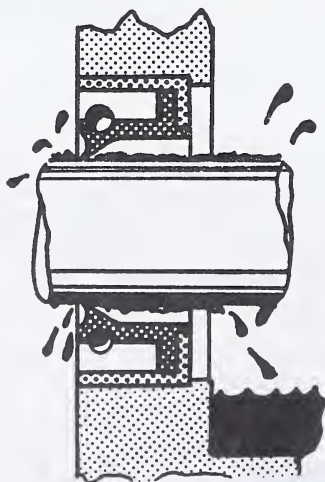


Double sealing lips to separate two fluids or to keep fluid in and dust or water out.



Double sealing lips both of which contain oil from this side only.

If the sealing lip does not face the fluid to be contained, the seal will leak. Be extremely careful when replacing a seal. Ensure the sealing lip is facing in the proper direction.



Seal lip is facing the wrong way.  
Oil will leak from the system.

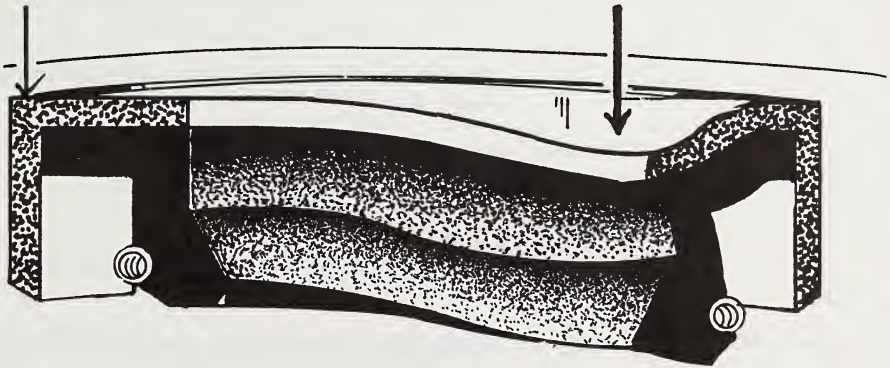


Seal lip is facing the correct way.  
No oil will leak from the system.

Care must also be exercised to make sure seals have been installed squarely in their recesses. Damaged or crooked seals will not contain fluid properly.

Apply pressure evenly around the entire seal case at point X to install seal.

Seal case damaged by careless installation. This distorts the sealing lip and causes leakage.



### SELF-CORRECTING EXERCISE 1

Which fastener or fasteners discussed in the lesson notes is **best** for each of the following jobs?

1. \_\_\_\_\_ Fastening larger parts where close tolerances are not required.
2. \_\_\_\_\_ Permanently fastening two pieces of sheet metal together.
3. \_\_\_\_\_ Attaching a V-pulley to a motor
4. \_\_\_\_\_ Keeping a shaft from sliding out of place
5. \_\_\_\_\_ Attaching a cylinder head to an engine block
6. \_\_\_\_\_ To install a tow hook to the front of a truck frame
7. \_\_\_\_\_ Bolting a voltage regulator to the fender liner of a vehicle.
8. \_\_\_\_\_ To prevent a bearing from moving out of position

**SELF-CORRECTING EXERCISE 2**

In the space provided at the left, write the letter **T** if the answer is true or **F** if the answer is false for the following questions.

- \_\_\_\_\_ 1. All seals contain fluid from both directions.
- \_\_\_\_\_ 2. Seals are only used to contain lubricants.
- \_\_\_\_\_ 3. Friction bearings carry a larger load than antifriction bearings of the same size.
- \_\_\_\_\_ 4. Broken fasteners must be drilled out.
- \_\_\_\_\_ 5. Pop rivets require several light hammer blows to set them.
- \_\_\_\_\_ 6. Lockwashers help prevent fasteners from working loose.
- \_\_\_\_\_ 7. Pointed setscrews are used to permanently install parts on a shaft.
- \_\_\_\_\_ 8. Wing nuts are used when frequent adjustment of parts are required.
- \_\_\_\_\_ 9. Antifriction bearings do not require lubricant.
- \_\_\_\_\_ 10. An impact wrench will aid in the loosening of frozen fasteners.

**SELF-CORRECTING EXERCISE 3**

Answer the following multiple choice questions by inserting the letter of the best choice in the space to the left of the question.

- \_\_\_\_\_ 1. Tensile strength is
  - (a) the amount of torque.
  - (b) the ability of a material to resist being pulled apart.
  - (c) the measurement of the shock load a fastener will withstand.
  - (d) the amount of increase in strength of a fastener as its length increases.

- \_\_\_\_\_ 2. The amount of torque required to properly tighten a grade 5 1/2-13 cap screw is
- (a) 52.88 N•m.
  - (b) 55.89 N•m.
  - (c) 101.69 N•m.
  - (d) 115.24 N•m.
- \_\_\_\_\_ 3. Cap screws are made
- (a) with flat heads.
  - (b) with socket heads.
  - (c) with both of the above head shapes.
  - (d) with neither of the head shapes listed in answers (a) and (b).
- \_\_\_\_\_ 4. Before applying heat to free “frozen” fasteners
- (a) care should be taken to avoid damage to surrounding parts.
  - (b) care should be taken to avoid fire.
  - (c) experience in the use of a torch is necessary.
  - (d) All of the above answers apply.
- \_\_\_\_\_ 5. When a broken stud projects slightly above the casting, it can be removed by
- (a) filing two sides flat, then using a wrench.
  - (b) using heat to free the fastener.
  - (c) using a punch to free the fastener.
  - (d) using a stud extractor.
- \_\_\_\_\_ 6. The garter spring installed on the sealing lips of oil seals
- (a) holds the seal parts together.
  - (b) increases the sealing pressure on the seal lip.
  - (c) indicates which side of the seal faces inward.
  - (d) makes the oil seal seat tighter in the casting.



Complete the following exercises and send them in for correction.

**EXERCISE 1**

1. Which type of nut is designed to resist working loose when subjected to vibration?

---

2. Why are sheet metal screws sometimes referred to as self-tapping screws?

---

---

3. Why are pop rivets preferred over conventional rivets?

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4. Briefly explain the best procedure to follow in removing a stud which has broken off 10 mm below the surface of the casting.

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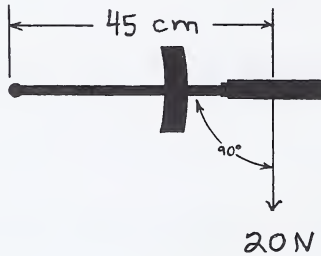
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5. Why is a die not the best tool to use when restoring damaged threads?

---

---

6. What would be the torque reading on the torque wrench shown below?



7. Why are paper gaskets unsuitable for sealing cylinder heads to engine blocks?

---

---

8. What often happens if the gasket surfaces of castings are not cleaned prior to reassembly?

---

9. List the two major types of bearings.

(a) \_\_\_\_\_

(b) \_\_\_\_\_

10. What is the difference between a gasket and a seal?

---

---

**ANSWERS TO SELF-CORRECTING EXERCISES****Self-Correcting Exercise 1**

1. machine bolt (page 2)
2. pop rivet (page 11)
3. set screw (page 7)
4. snap ring (possibly set screw) (page 10)
5. stud bolt (page 8) or cap screw (page 6)
6. machine bolt (page 2)
7. machine screw (page 1) or sheet metal screw (page 8)
8. snap ring (page 10)

**Self-Correcting Exercise 2**

1. false (page 20)
2. false (pages 19-20)
3. true (page 18)
4. false (pages 13-14)
5. false (page 11)
6. true (page 9)
7. true (page 7) (The sharp points cuts into the shaft.)
8. true (page 5)
9. false (page 18 — transmissions, differentials, etc. contain lubricating oil)
10. true (page 12)

**Self-Correcting Exercise 3**

1. b (page 2)
2. c (page 4)
3. c (page 6)
4. d (page 12)
5. a (page 13)
6. b (no direct reference)

**END OF LESSON 6**

# **Mechanics 12**

## **Module 2**

# **ENGINE ELECTRICAL SYSTEMS**



**Distance  
Learning**

**Alberta**  
EDUCATION



## LESSON RECORD FORM

1746 Mechanics 12  
Module 2

### FOR STUDENT USE ONLY

Date Lesson Submitted

(If label is missing  
or incorrect)

File Number

Time Spent on Lesson

Lesson Number \_\_\_\_\_

### Student's Questions and Comments

Apply Lesson Label Here

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Postal Code \_\_\_\_\_

*Please verify that preprinted label is for  
correct course and lesson.*

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Lesson Grading: \_\_\_\_\_

Additional Grading  
E/R/P Code: \_\_\_\_\_

Mark: \_\_\_\_\_

Graded by: \_\_\_\_\_

Assignment Code: \_\_\_\_\_

Date Lesson Received: \_\_\_\_\_

Lesson Recorded \_\_\_\_\_

Teacher's Comments:

Correspondence Teacher

## **ALBERTA DISTANCE LEARNING CENTRE**

### **MAILING INSTRUCTIONS FOR CORRESPONDENCE LESSONS**

#### **1. BEFORE MAILING YOUR LESSONS, PLEASE SEE THAT:**

- (1) All pages are numbered and in order, and no paper clips or staples are used.
- (2) All exercises are completed. If not, explain why.
- (3) Your work has been re-read to ensure accuracy in spelling and lesson details.
- (4) The Lesson Record Form is filled out and the correct lesson label is attached.
- (5) This mailing sheet is placed on the lesson.

#### **2. POSTAGE REGULATIONS**

Do not enclose letters with lessons.

Send all letters in a separate envelope.

#### **3. POSTAGE RATES**

First Class

Take your lesson to the Post Office and have it weighed. Attach sufficient postage and a green first-class sticker to the front of the envelope, and seal the envelope. Correspondence lessons will travel faster if first-class postage is used.

Try to mail each lesson as soon as it has been completed.

When you register for correspondence courses, you are expected to send lessons for correction regularly. Avoid sending more than two or three lessons in one subject at the same time.

## BASIC ELECTRICITY

Introduction  
Basic Electricity  
Magnetism  
Batteries  
Testing Conventional Batteries  
Charging Batteries

### INTRODUCTION

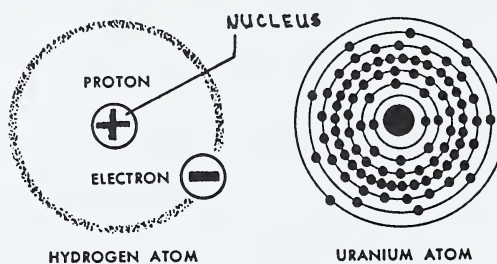
Electricity performs many important functions in the vehicle and equipment field. Electricity is used to:

1. Supply the power required in order to turn over an engine for starting.
2. Provide the spark for each cylinder of an internal combustion engine.
3. Provide power to operate the lights on a vehicle such as headlights, tail lights, stop lights, signal lights, warning lights, etc.
4. Sound the horn.
5. Provide power for electrical gauges such as fuel level gauge and temperature gauge.
6. Supply power for electrical accessories such as heater, radio, windshield wipers, rear defogger, etc.
7. Power a variety of magnetically operated controls such as the starter switch and shift controls in the automatic transmission.
8. Supply the power required in order to keep the batteries charge level at an acceptable amount.

## BASIC ELECTRICITY

Before you can understand what electricity is, you first have to have a basic picture of an atom.

All materials are made up of atoms and all atoms contain particles. Of these particles there are two types in the nucleus, one is a neutron which has no charge associated with it and the other is the proton which has a positive charge. Orbiting around the nucleus are the negatively charged electrons. The number of particles in an atom is dependent upon the type of material, so some materials will have many more particles than others. If, for example, we consider an atom of hydrogen gas, it has only one proton in the nucleus and one electron in orbit around this nucleus. Hence we have one positive particle and one negative particle. These two particles attract each other (Note: unlike particles attract each other and like particles repel). The hydrogen atom is the simplest atom available. Uranium, on the other hand, is one of the most complex elements with 92 electrons and 92 protons.



*Courtesy of John Deer Ltd.*

In their natural state atoms have an equal number of positive protons and negative electrons. The atoms are, therefore, electrically neutral. This neutral state can be altered, however. If an electron is attracted away from an atom, the atom will have a positive charge since it will have one more proton than electron. Likewise, if an electron is added to an atom, the atom will have a negative charge because it has one extra electron.

If it were not for the attractive force between positive and negative particles then the centrifugal force of the orbiting electron would cause it to leave the atom. As long as the energy of the two particles is nearly the same the electron will stay in orbit around the proton. If we supply the electron with more energy it will eventually be much stronger than the attractive force of the proton and it will leave the orbit around the nucleus. Electrons which have enough energy to do this are called free electrons. Atoms often lose their electrons in this fashion and then retrieve electrons from other atoms as they lose their energy. When these "lost" electrons gather in one area, that area then has a surplus of electrons and therefore a charge of negative electricity. If there is then a path connected to this area, along which these electrons can flow, they will move away from this area to a place that has atoms which are short of electrons. This movement is then called a flow of electrical current.

Study this example. The element copper is widely used in electrical systems because it is a good conductor of electricity. The reason for copper's good conductivity can be explained by looking at a diagram of its atom.

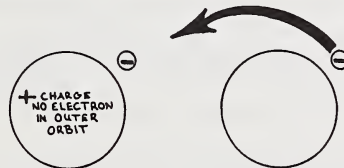


*Courtesy of John Deer Ltd.*

The copper atom has 29 electrons placed in four separate shells or rings. Notice that the outer ring has only one electron. It is this one electron which makes copper such a good conductor of electricity.

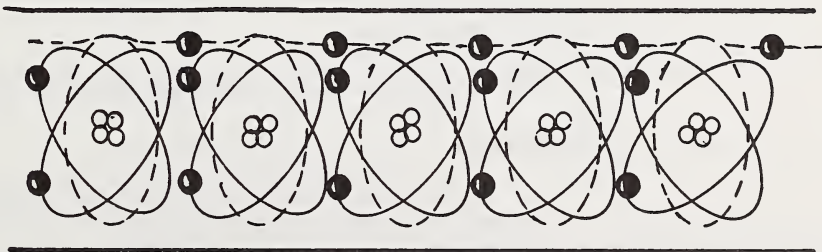
Since there is only one electron in the outer orbit (where many electrons could be placed if available) and because the one electron is quite a distance from the nucleus (which attracts the electron to the atom), the copper atom does not hold the electron strongly. They are loosely bound. Hence the copper atoms tend to both give up or accept an electron in their outer orbit quite readily.

Consider a copper wire composed of many copper atoms in a row with a positively charged atom at one end (no electron in the atom's outer ring) and an atom with negative charges at the other end (the atom has an extra electron, that is, two electrons in its outer ring). Since positive charges attract negative charges, the positively charged first atom will attract the negatively charged electron in the outer orbit of the second atom.



This electron will jump over to the charged atom giving the atom the electron it was missing in its outer ring.

The first atom has achieved a neutral state. The second atom is left with no electrons in its outer ring so it has a positive charge. This positive charge attracts the negatively charged electron from the third atom. The third atom will attract an electron from the fourth, the fourth from the fifth, and so on. The second to last atom will take an electron from the last atom which being negatively charged has two electrons in its outer orbit. All the atoms will now have the proper number of electrons in the outer ring. In this process electrons have passed from atom to atom. They are drawn to the positive end along the line of atoms from the negative end.



Electron movement or "drift" from one atom to another.

In terms of the direction that the electrons move, a flow of electrons has taken place from the negative end to the positive end. This is the definition of electricity.

**Electricity is the flow of electrons from atom to atom in a conductor in the direction of negative to positive.**

In a copper wire there are billions of copper atoms and hence billions of electrons will be moving. The electrons will continue to flow as long as the positive and negative charges are maintained at each end of the wire.

By adding new electrons to the negative end of the wire and removing electrons from the positive end of the wire as they get there (this is what a battery does) the electrons or electric current will flow.

The basic idea of electricity is by no means an easy concept to understand. Electricity is said to flow in a circuit similar to how water flows in a hose. However, water can be seen and felt while electricity is not such a substance. You cannot point to an object and say "that is electricity." Rather, electricity is a force of attraction that causes electrons in a conductor to move and thus have energy. Having no substance itself, the force of electricity uses the substance of the conductor to carry its energy. The effects of electricity can be felt and the results of its energy can be seen but electricity itself cannot be looked at and seen.

Thus we can say that the electron movement is caused by a combination of two conditions: Like charges always repel and unlike charges always attract. When we connect an electric circuit or path to a battery, the electrons will flow from the negative terminal of the battery through the electron path to the positive terminal. If we break this path at any point the electrons stop moving and must again wait for a path to travel on. As long as a battery is operative, there is a concentration of electrons at the negative terminal and a shortage of electrons in the area of the positive terminal. Electrons being concentrated in one area and deficient in another area is a result of the chemical action within the battery.

As long as this chemical action produces this unbalanced condition and a path is provided for the electrons they will try to flow back to the positive terminal to attain a balance once more. The condition required for electrons to flow through the path (conductor) is that the conductor must be made up of atoms having a lot of free electrons. If the atoms which make up a material, have very few or no free electrons then the electrons at the negative terminal will not be able to flow. The other condition is that they must have some place to flow to. If you only connect to the negative terminal and the other end of the conductor does not attach to a place that has a shortage of electrons then no flow will take place.

## 1. Basic Electrical Factors

There are three basic factors of electricity. These are current, voltage and resistance.

### (a) Current

The flow of electrons through a conductor is called an electrical current and it is measured in amperes. One ampere is a current of 6.28 billion billion electrons passing a given point in a conductor in one second. The current (or amperage) of a circuit is, then, a measure of how many electrons are flowing in the circuit.

The formula symbol for current is  $I$  and the unit symbol for amperes is  $A$ . For example, if the current through a conductor is forty amperes this could be written as  $I = 40 A$ .

There are two forms of electric current, direct current (DC) and alternating current (AC). Direct current travels in one direction only while alternating current constantly reverses direction. Automotive electrical systems are mainly DC while household and industrial electrical systems are mainly AC. In this course you shall study only DC current.

**(b) Voltage**

One end of a current carrying conductor has a positive charge while the other has a negative charge. The strength of the charge depends on how many extra electrons there are at the negative end or conversely how many electrons are missing at the positive end.

The greater the number of extra electrons (or missing electrons) the greater the charge or the difference between the two ends. Voltage is the term used to measure the strength or force of the attraction between the positive and negative charges. The stronger the charges at either end the greater the force of attraction between one another (or their voltage).

Voltage is measured in volts. The formula symbol for voltage is  $V$  and the unit symbol for volts is  $V$ . For example, if the voltage applied to a component is twelve volts then this would be written as  $V = 12 V$ .

You should note that voltage is a potential force and can exist even when there is no current flow. For example, a storage battery can have a potential of twelve volts between its positive and negative terminals, and this potential exists even though no conductors are connected to the posts.

**(c) Resistance**

All conductors offer some resistance to the flow of current. Resistance is caused by

- (i) each atom resisting the removal of an electron due to its attraction toward the core.
- (ii) collisions of countless electrons and atoms as the electrons move through the conductor.

In a vehicle's circuit the resistors are the electrical accessories, the lights, the electrical motors, gauges, etc.

Resistance is measured in ohms. One ohm is the resistance that will allow one ampere to flow when the potential is one volt. The formula symbol for resistance is  $R$  and the unit symbol for ohms is  $\Omega$ . For example, if a component has a resistance of twenty ohms this may be written as  $R = 20 \Omega$ .

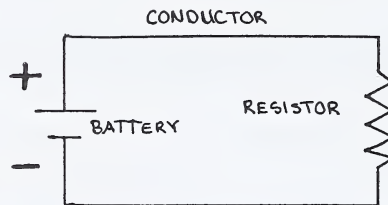
## 2. Electric Circuit Versus A Water Pump Circuit

The chart below compares an electrical circuit with a water pump circuit. This chart may help you to understand the relationship between voltage, current, and resistance.

Element Compared	Water Pump Circuit	Electric Circuit
circuit	water flows in hoses to operate a device (e.g. sprinkler)	electrons flow in copper wires to operate electric accessories
source of energy	pump	battery, generator
flow rate	litres per minute	amperes (electrons per second (I))
working energy	pressure	voltage (V)
resistance	friction loss	ohm (R)

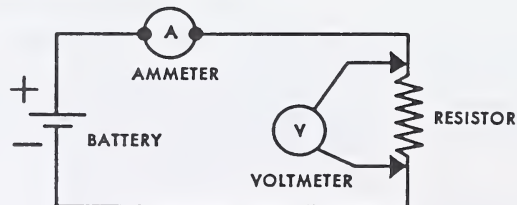
## 3. Basic Electrical Circuits

A basic electrical circuit has three parts to it.



- a voltage source such as a battery
- a resistor such as a light bulb
- a conductor such as copper wire to connect the circuit

An ammeter is used to measure the current in an electrical circuit while a voltmeter measures the voltage and an ohmmeter the resistance.



*Courtesy of John Deere Ltd.*

Knowing the basic information about an electrical circuit means knowing the number of volts, amps, and ohms in the circuit. An electrical formula called Ohm's Law relates these three quantities.

**(a) Ohm's Law**

A scientist, George Ohm, recognized a relationship between current flow, voltage, and resistance and devised an electrical formula (called Ohm's Law) to relate these three quantities.

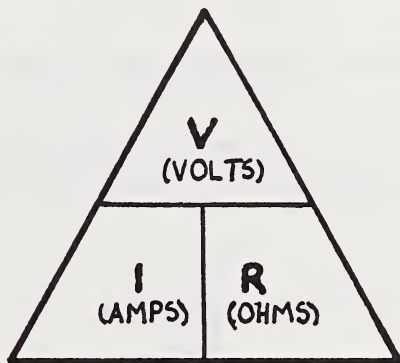
$$V \text{ (volts)} = I \text{ (amperes)} \times R \text{ (ohms)}$$

$$V = IR$$

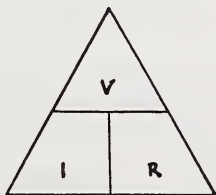
$$I = \frac{V}{R}$$

$$R = \frac{V}{I}$$

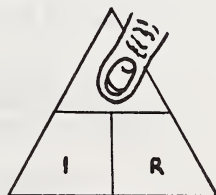
If you know any two of the quantities you can find the third by applying the above formulas. For example, if you know the amps (I) and the ohms (R), multiplying the amps times the ohms will give the volts (V). Or if you know the ohms (R) and the volts (V), dividing the volts by the ohms will give the amps. An easy way to remember these formulas is by using the triangle shown below.



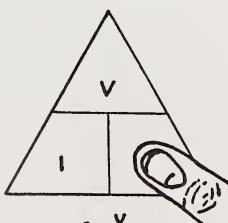
To use the above triangle merely cover the factor you are trying to find. Look at the triangle, as you read these formulas,  $V = I \times R$ ,  $I = \frac{V}{R}$  and  $R = \frac{V}{I}$  to see how the triangle works.



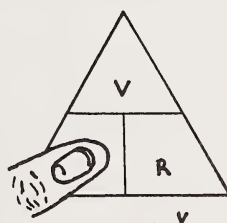
I = AMPERES (CURRENT)  
R = OHMS (RESISTANCE)  
V = VOLTS (VOLTAGE)



$$V = I \times R$$



$$R = \frac{V}{I}$$



$$I = \frac{V}{R}$$

**EXAMPLE 1:** If a circuit has a resistance of  $4\ \Omega$  and a voltage of  $12\ \text{V}$  applied to it, how much current will flow?

Solution: The voltage and resistance values are known so use Ohm's Law to solve for the current.

$$\begin{aligned} I &= \frac{V}{R} \\ &= \frac{12\ \text{V}}{4\ \Omega} \\ &= 3\ \text{A} \end{aligned}$$

A current of  $3\ \text{A}$  will flow through the circuit.

**EXAMPLE 2:** How much voltage is required in order to send a current of  $5\ \text{A}$  through a  $8.2\ \Omega$  resistor?

Solution: The current and resistance values are known so solve for the voltage.

$$\begin{aligned} V &= I \times R \\ &= 5\ \text{A} \times 8.2\ \Omega \\ V &= 41.0\ \text{V} \end{aligned}$$

A voltage of  $41\ \text{V}$  is required for the circuit.

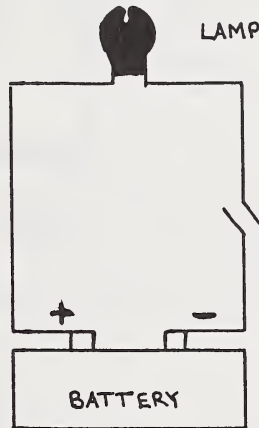
#### 4. Electrical Insulators and Conductors

A conductor is any substance that is a good transmitter of electricity. All metals and many liquids are considered conductors. In general, any substance composed of atoms that have less than four electrons in its outer orbit is a conductor.

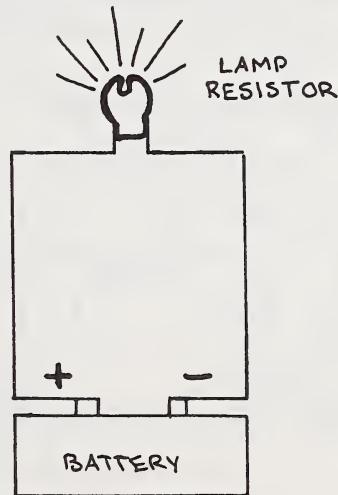
An insulator is opposite to a conductor. An insulator is any substance that is a poor transmitter of electricity. Insulators usually have more than four electrons in their atom's outer ring. Glass, plastic, mica, and rubber are examples of insulators.

### 5. Open, Closed and Shorted Electrical Circuits

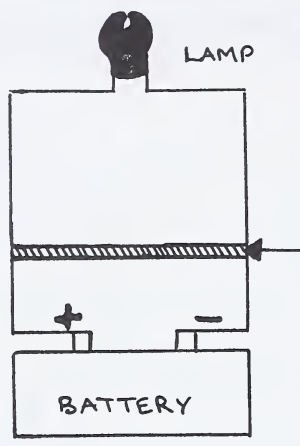
In an open circuit the circuit path is opened by either a switch or a broken wire. In the diagram below current cannot reach the light because its path is broken. All light circuits in homes are open circuits when the switch is in the off position.



A closed circuit has a circuit path with no breaks in it plus a resistance to control the amount of current flow. The drawing below shows a closed circuit.



A short circuit occurs in a circuit when the current can take a shorter path, bypassing the route it was supposed to take. In the diagram below the lamp will not light because the current is short circuited.



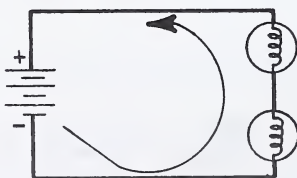
CONDUCTOR CREATING A SHORT CIRCUIT

In a short circuit there is little resistance since the current is not travelling through the resistor (the lamp). Looking at the formula  $I = \frac{V}{R}$ , if the resistance is very low because of the short circuit, this means the current will be large. In fact, it would be so large that the conductor would be burned up and destroyed.

## 6. Types of Electrical Circuits

There are three types of electrical circuits in use: series, parallel, and series-parallel.

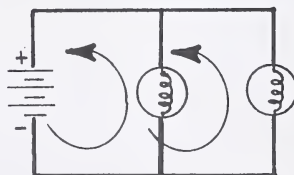
### (a) Series Circuit



ONE CURRENT PATH

In a series circuit the components are connected end to end as shown in the figure to the left. The same current flows through all components. The current flows through one lamp, then through the other lamp before returning to the source. If one lamp burns out, then both lamps must go out since the burnt out lamp cuts off the path for current to flow.

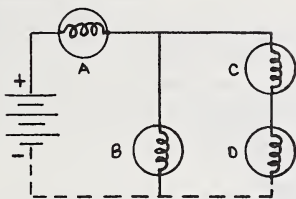
### (b) Parallel Circuit



TWO CURRENT PATHS

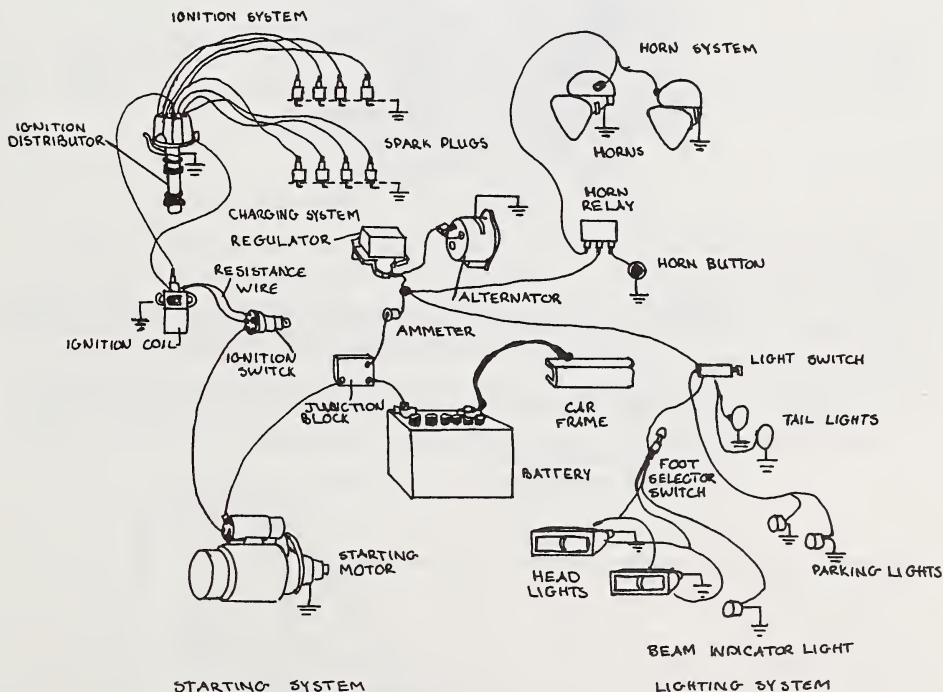
In a parallel circuit the components are connected across each other so there are two or more paths for current to flow. In the drawing to the left the current divides so that part of the current flows through one lamp, while the remainder flows through the other lamp. If one lamp burns out, all current will flow through the other lamp.

## (c) Series Parallel Circuit



In many circuits a parallel circuit is connected in series with one or more components as shown to the left. This results in a series-parallel circuit being produced. Lights C and D are in series with each other, but in parallel with light B. This entire circuit is then in series with lamp A. Series-parallel circuits are not commonly found on vehicles.

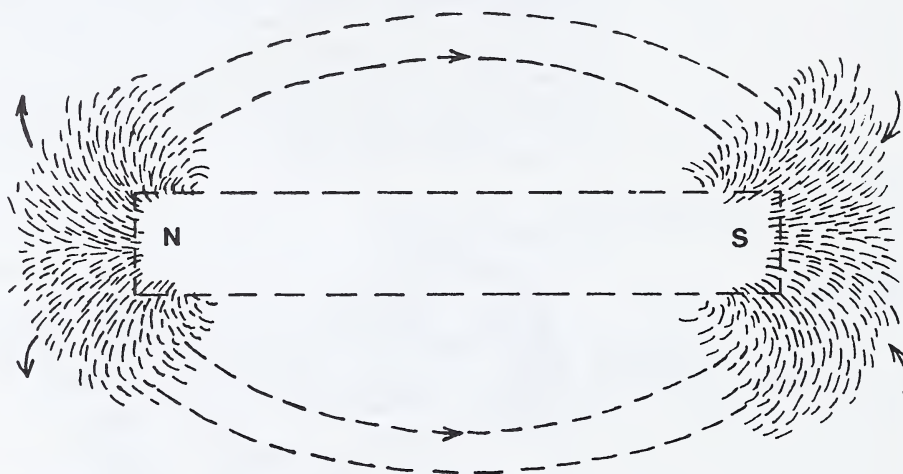
The major units (starter, alternator, etc.) of a vehicle's electrical system are connected in parallel while the minor units (such as switches and control units) are connected in series with the units that they correspond to. Study the illustration below of a typical automobile electrical system. It shows the major electrical units and the connections between them. The symbol  $\text{---}\text{||}\text{---}$  means a ground point (such as a car's frame or engine). Using the car's frame or engine as the electrical return circuit means that only about half as much wiring is required than if regular wiring was used for the return circuit.



## BASIC MAGNETISM

Most of the electrical units in an automobile use not only electricity but also magnetism which is produced by the electricity. There are many electro-magnetic units including any electric motor, regulator, horn, coil, generator, solenoid and cut out relay to name but a few. Permanent magnets (those that do not need electricity) are used in analog style gas gauges, ammeters and speedometers.

A permanent magnet is obtained by magnetizing a piece of hard steel. The size and shape of a magnet's field may be found by placing a thin sheet of paper over the magnet and sprinkling fine filings onto the paper, then if you tap the paper, the filings will move into the lines of magnetic force projected by the magnet.



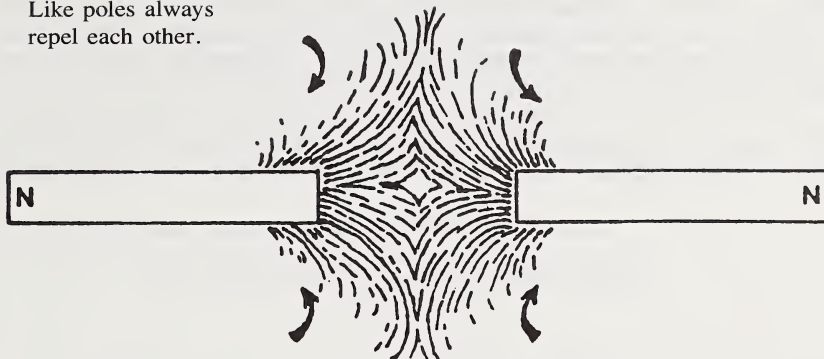
**Note:** The heaviest concentration of the filings will always be at the ends of the magnet where the magnetic fields are most intense.

These ends of the magnet are designated North (N) and South (S)

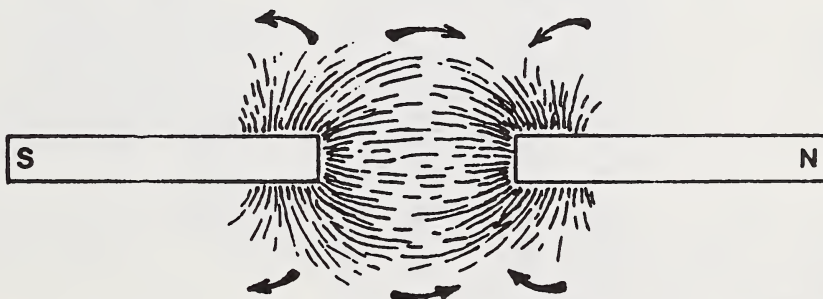
N - north seeking pole

S - south seeking pole

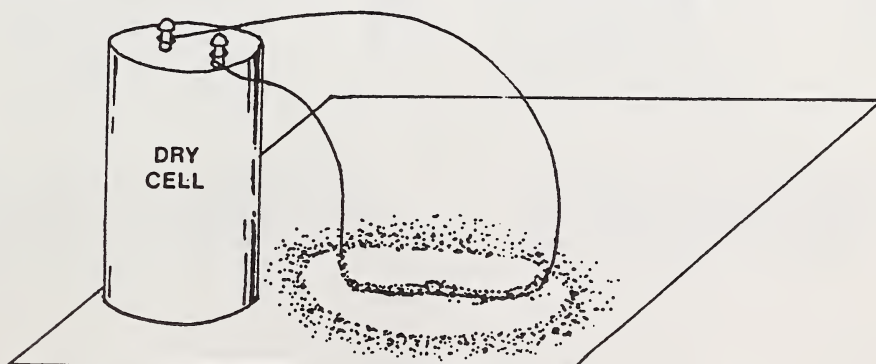
**Note:** Like poles always repel each other.



Unlike poles always attract each other.



Whenever an electron is in motion, a magnetic field surrounds that electron. By field we mean that area around the electron in which magnetism can be detected. When an electric current flows through a conductor, a magnetic field surrounds that conductor. It has been found that the field around a conductor is the sum total of the field around all of the electrons moving in that conductor. Therefore, it has an intensity which is directly proportional to the current in the conductor. If you triple the current the intensity of the magnetic field will triple. We know that magnetic fields will attract iron and steel. If you are skeptical obtain some very fine iron or steel filings and a battery and try the following experiment.

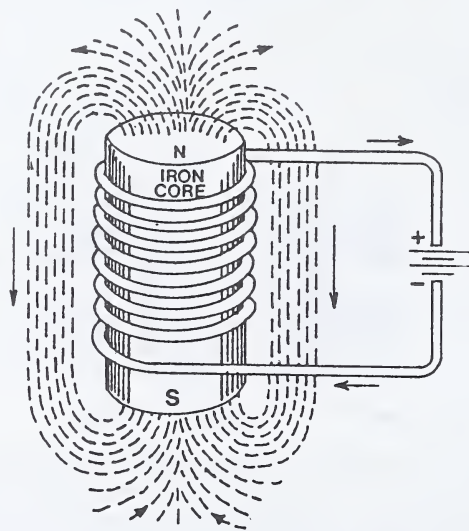


The magnetic field around the wire will attract the iron filings. If you add another battery in series with the first one it will approximately double the number of filings attracted.

In an electric motor it is magnetic attractions and repulsions which rotate the armature and thus change electrical power into rotating mechanical power. In a generator the process is reversed. Mechanical power is converted to electrical power.

Like electricity, a magnetic field must also have a closed circuit where the N and S poles correspond to the previously mentioned positive and negative terminals. The only difference is that man made conductors are not needed for a magnetic field.

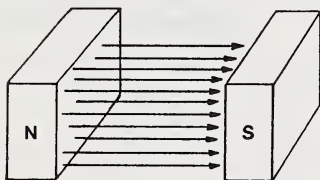
A coil of wire with a current running through it is called a solenoid. Solenoids intensify and concentrate the electromagnetic force. By inserting an iron core inside of the coil the electromagnetic force can be concentrated more.



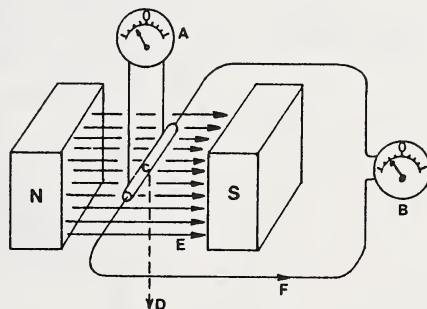
Generator and motor armatures, field poles, and ignition coil, are all solenoids.

The iron core of a solenoid is constructed of soft iron so that it will lose all of its magnetism as soon as the circuit is broken. A magnetic field represents stored magnetic energy. The magnetic field strength is increased or decreased by increasing or decreasing the amount of current flow. As long as the current flow is constant the magnetic field will remain constant.

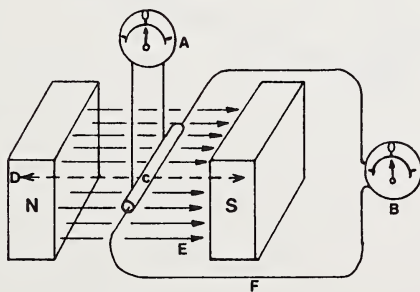
The four illustrations shown below indicate how a simple generator can operate. Notice how the magnetic field can produce a current flow in a conductor when certain conditions are met.



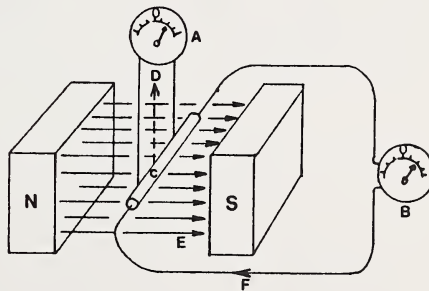
A simplified sketch of a magnetic field between two poles.



When conductor C moves at right angles (D) to the field E it causes voltage A (called an induced voltage) which in turn creates a current B to flow in external circuit F.



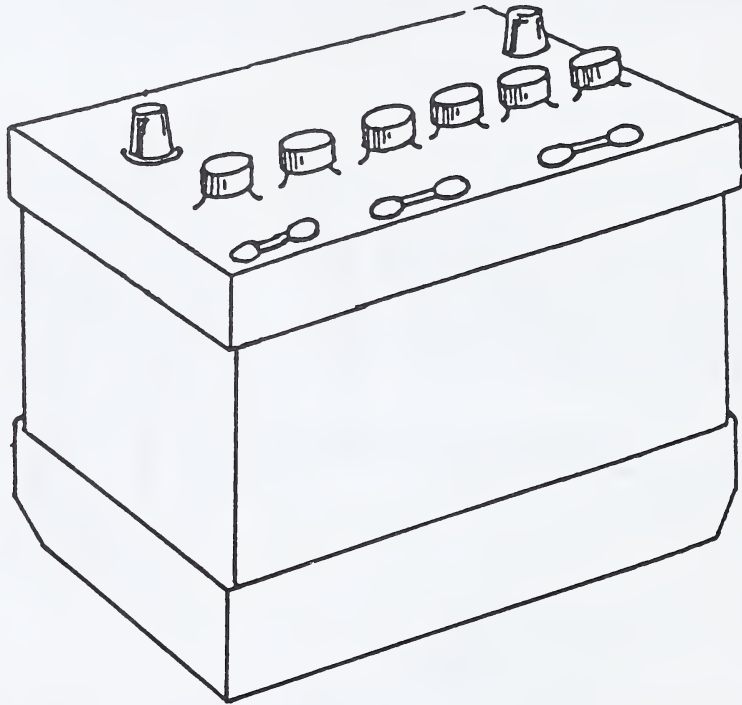
No voltage A is generated when the conductor C is moved parallel (D) with the field E. As a result no current B flows in circuit.



If conductor C is reversed from that above then the magnitudes stay the same but directions are reversed.

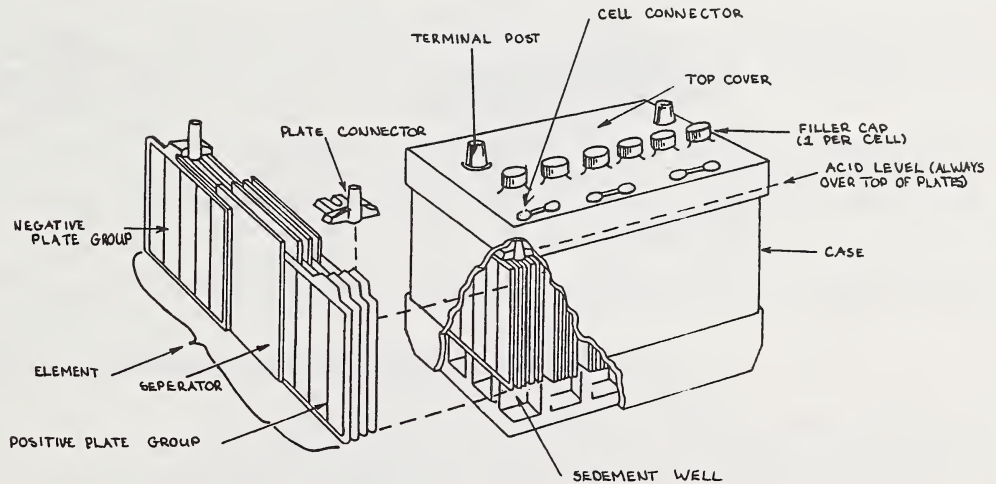
## STORAGE BATTERIES

A battery stores energy for all the electrical circuits (such as starting, ignition, and accessory) in a vehicle. When required the battery produces a flow of current to operate the electrical components in these circuits. A battery does not store electrical energy. It stores chemical energy which can be converted into electrical energy. This, in turn, can be converted into mechanical energy through the use of electric motors (for example, the power windows in a car).



## 1. Battery Construction

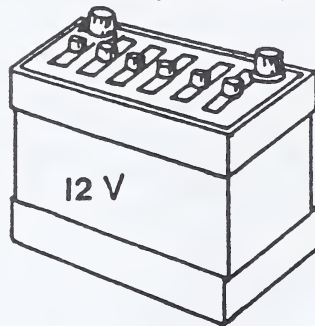
A battery is made up of a number of individual cells in a hard rubber or plastic case. The basic units of each cell are the positive and negative plates. Negatively charged plates have a lead surface (gray in colour) while positively charged plates (brown colour) have a lead peroxide surface. Both negative and positive plates are bonded together in separate groups. Plate groups are interconnected as shown below.



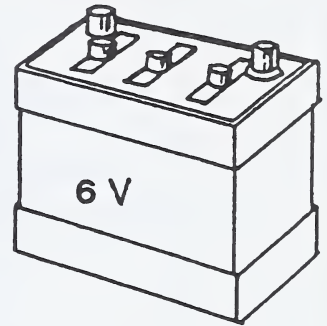
SECTIONAL VIEW OF A 12 VOLT BATTERY

Each plate or plate group is kept apart through the use of porous separators. These separators allow the free flow of electrons around the active plates. The complete plate assembly is called an element.

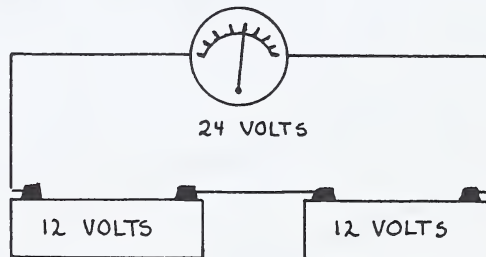
Elements in different cells are connected in series. The cells are separate from one another so there is no flow of electrolyte between them. It does not matter how big or how small we make each cell of a battery because the chemical process can only develop a voltage of about 2 V. For a 6 V battery this means 3 cells are required while a 12 V battery would require 6 cells.



Note:  
only external  
difference  
is the number  
of filler holes  
depicting the  
number of cells



For higher voltages, combinations of batteries are connected in series. Two 12 V batteries connected in series combine to give 24 V.



Batteries of the same voltage can produce different amounts of current. The amount of current a battery can produce is dependent on the number of plates, the size of the plates, and the amount of electrolyte in the battery. The more plates there are the more chemical reactions that can take place between the electrolyte and the plates and hence the greater the amount of current that can be produced. The larger the plate area and greater the quantity of fluid then the longer it takes to cover the plates with lead sulphate and dilute the sulphuric acid.

Modern batteries therefore are designed to bring the largest possible plate area into contact with the acid in the most compact manner possible. As can be seen, if you have the room for it, you can use any size battery in your vehicle as long as it is of the correct voltage. The larger the battery the longer it will last under normal usage. Internal components of the battery though are always similar.

Batteries have negative and positive posts (or terminals). The positive post is slightly larger than the negative in order to help prevent the battery from being connected in reverse polarity. The positive terminal has a "+" or "pos" identifying mark on or near it while the negative terminal has a "-" or "neg" mark near it.

Conventional batteries have filler caps in each cell. These caps cover access holes through which the electrolyte level in each cell can be checked and water added if needed. The access holes also provide a vent to allow gas to escape when the battery is being charged. Maintenance free batteries are a new style of battery in which no filler caps are included. They are discussed later in this lesson.

## 2. How the Battery Works

It has been mentioned that a battery produces current for the systems of a vehicle. This current is produced by the chemical reaction between the active materials of the battery plates and the sulphuric acid solution in the battery.

If two different metals are placed in an acid solution which can attack them, an electrical potential (or voltage) is created. If wires are connected from these two metals into a closed circuit then current will flow. Over time the reaction of the acid will change the two metals into the same metal and the reaction will cease.

More information can be gained on how the battery works by studying the cycles that a battery goes through.

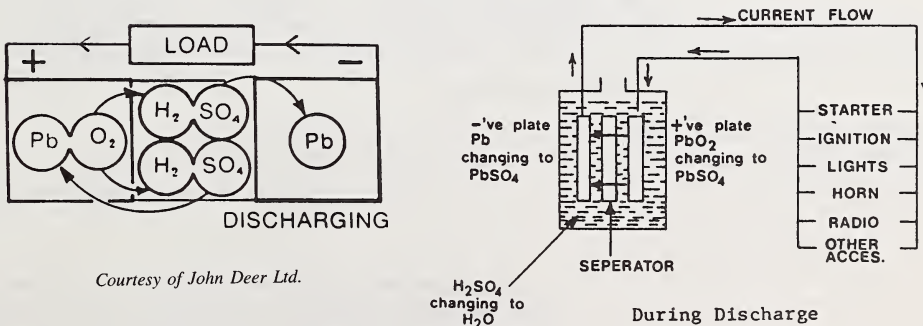
### (a) Battery Operating Cycles

Essentially a charged battery consists of two different metals immersed in a solution of sulphuric acid. One of the metals, lead peroxide ( $\text{PbO}_2$ ), forms the positive plate. The other metal is pure lead ( $\text{Pb}$ ) and forms the negative plate. The acid solution is commonly called the electrolyte.

A battery has two operating cycles; a discharge cycle and a charging cycle.

#### (i) Discharging cycle

In the discharging cycle the battery is supplying current so it is discharging. This means electrons are leaving the negative terminal, flowing through the circuit, and returning to the positive terminal. The chemical reactions in a discharging battery are as follows.



*Courtesy of John Deer Ltd.*

The positive plates are made of lead peroxide ( $\text{PbO}_2$ ). The lead ( $\text{Pb}$ ) reacts with the sulphate ( $\text{SO}_4$  in the electrolyte ( $\text{H}_2\text{SO}_4$ )) to form lead sulphate ( $\text{PbSO}_4$ ). At the same time oxygen ( $\text{O}_2$ ) in the lead peroxide joins with the hydrogen ( $\text{H}$ ) in the electrolyte to form water ( $\text{H}_2\text{O}$ ).

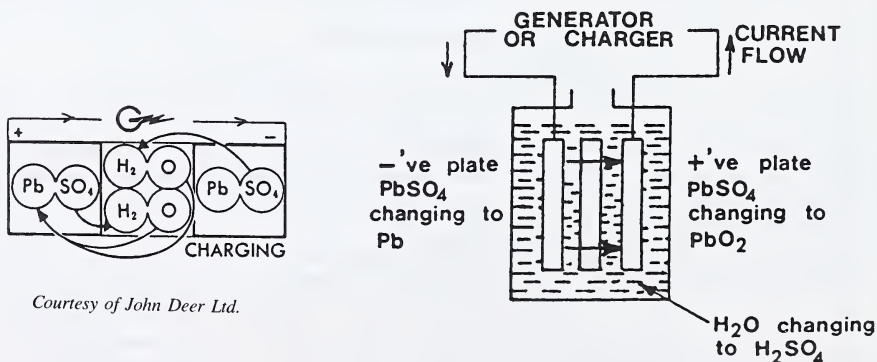
The negative plates are made of lead. This lead combines with the sulphate in the electrolyte to form lead sulphate. The diagrams above illustrate the discharge principle.

In the discharging process lead sulphate forms on both the positive and negative plates making the two plates similar. It is the sulphate deposits which account for cell voltage loss since voltage depends on the difference between the positive and negative plates. As the discharging cycle continues more lead sulphate is formed at the plates while more water is formed in the electrolyte.

## (ii) Charging cycle

In the charging cycle the battery is receiving current so it is charging. The generator/alternator is forcing electrons onto the negative terminal and removing them from the positive terminal. The chemical reactions which take place in this cycle are the reverse of those occurring during the discharging cycle.

The sulphate leaves the plates and goes back into the electrolyte to strengthen the sulphuric acid solution. At the same time oxygen from the water in the discharged electrolyte joins with the lead at the positive plate to form lead peroxide.



*Courtesy of John Deer Ltd.*

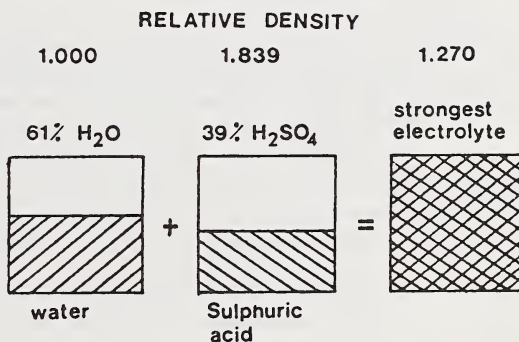
## During charge

It is important to remember that a battery operates in a charging circuit with a generator or alternator. As the battery supplies current to various circuits it will become discharged. It is the generator/alternator unit which sends current to the battery to recharge it. Operation of this recharging varies with engine speed.

At higher operating speeds the generating system supplies enough current to operate the vehicles system plus recharge the battery. When the engine is running very slowly (such as at idle) the generator/alternator may not produce enough electricity. The battery is then called upon to make up the deficit. If this drain is continued for too long the battery will run down and an outside charging source is required to recharge the battery. When the engine is shut off, the battery alone is used to supply current to the circuits.

### 3. Battery Electrolyte and Relative Density (commonly called specific gravity)

The electrolyte in a fully charged battery is a concentrated solution of sulphuric acid in water. It has a relative density of about 1.270 at 27°C, which means it weighs 1.270 times more than water. The solution in northern climates (because it is affected by temperature) is composed of about 39% sulphuric acid (which in its pure state has a relative density of 1.839), and 61% distilled water (which has a relative density of 1.000). These quantities are measured by weight and result in a fully charged cell with a relative density of about 1.270. This electrolyte is capable of producing 2.2 V maximum between the two plates.



**Composition of Electrolyte**

There is some breakdown in the process of discharging and charging a battery. Each time a battery is charged it loses some efficiency until eventually the battery wears out.

Using water with impurities in it affects the life and performance of a battery. While tap water and other types of water can be used in a battery, it is better for the battery if distilled water is used.

#### 4. Types of Batteries

There are three types of batteries in use today. These are the dry-charged battery, the wet-charged battery, and the maintenance free battery.

##### (a) Dry-charged batteries

A dry-charged battery contains fully-charged elements but has no electrolyte. It is activated by adding electrolyte. It then becomes a wet-charged battery.

A dry-charged battery will retain its full charge as long as moisture does not enter the cells. This type of battery should be stored in a cool, dry place. It will not lose any of its charge if stored this way prior to being used.

The activation of a dry-charged battery is done at the dealer's store when the battery is purchased. Most manufacturers supply packaged electrolyte for their dry-charged batteries along with instructions for activation. The instructions must be properly followed.

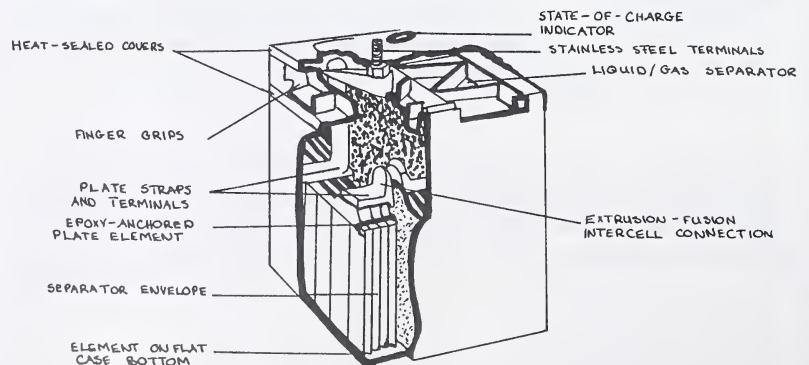
##### (b) Wet-charged batteries

Wet-charged batteries contain fully charged elements and are filled with electrolyte by the manufacturer. A wet-charged battery will not maintain its state of charge during storage. It must be recharged periodically since a slow reaction takes place between the electrolyte and the plates which causes the battery to lose its charge. This reaction is called self-discharge.

The rate at which self-discharge occurs varies according to the temperature of the electrolyte. A battery stored at a temperature of  $38^{\circ}\text{C}$  will be almost completely discharged after 90 days while if it is stored at  $15^{\circ}\text{C}$  the battery will be only slightly discharged after 90 days. Wet-charged batteries, should, be kept in the coolest place possible but which does not allow the electrolyte to freeze.

##### (c) Maintenance free batteries

Maintenance free batteries were developed to reduce the amount of battery maintenance and make the batteries more dependable and last longer. A maintenance free battery is similar in shape to a conventional battery but it has no filler caps. The electrolyte is completely sealed in the battery. Below are listed some of the characteristics of maintenance free batteries.



- (i) Since the electrolyte is sealed in a maintenance free battery the battery will have a lifetime supply of it. The battery level does not have to be checked and problems of overfilling or underfilling the cells are eliminated.
- (ii) Gases are produced during the charging and discharging cycles. The gases rise to the top of the case and are trapped by the liquid gas separator. They cool, condense, and then drain back to the electrolyte reservoir. Internal pressures which occurs is released through a vent hole located in the side of the cover.
- (iii) Some batteries have a state-of-charge indicator on the top of the battery cover. This indicator is a built-in hydrometer having a small green ball which floats when the specific gravity of the electrolyte is 1.225 or higher. The indicator is used to indicate if the battery is charged or discharged.

## 5. Capacity Ratings of Batteries

As was mentioned earlier in this course, there are several factors which influence battery capacity (the amount of current a battery can produce). These factors are the number and size of the plates plus the quantity and strength of the electrolyte. For example, if you have a 12 V battery from a D8 caterpillar tractor and a small 12 V battery from a Honda Civic, they are both 12 V batteries. If you drain them at a rate of 10 A per hour, for example, the small battery will become discharged a long time before the larger one.

In 1971 new capacity ratings for batteries were adopted by the Society of Automotive Engineers (SAE). There are two battery ratings now given. These are the cold power rating and the reserve capacity.

### (a) Cold power rating

The cold power rating indicates the amount of power a battery has for starting on cold days. The rating gives the number of amperes the battery (at  $-18^{\circ}\text{C}$ ) can deliver over 30 seconds and not fall below a voltage of 1.2 volts per cell. This is the minimum voltage required for dependable starting.

The cold power rating is the more important of the two ratings since it deals with the batteries main function, which is to start a vehicle. Many low priced batteries are rated at 200 amperes while more powerful and dependable batteries can deliver up to 525 amperes under the same conditions.

The cold power rating of the battery should match the power requirements of the engine it has to start. Using a battery which has a rating of 200 amperes would be inadequate if it had to supply 400 amperes to start an engine under very cold conditions.

**(b) Reserve Capacity**

The reserve capacity rating indicates the number of minutes a new fully charged battery will deliver 25 amperes at 27°C while maintaining a voltage of 1.75 volts per cell. 25 amperes is the typical power drain required to keep the ignition, lights, and other electrical accessories operating. This rating indicates how long the vehicle will operate if the generator or alternator fails. (If the charging system is inoperative, the reserve capacity will indicate how many minutes there is of battery operation before help is required.)

**6. Battery Safety**

When handling batteries the following safety precautions should be observed.

1. Wear eye and body protection (such as safety glasses and gloves)
2. Do not smoke. Do not work near open flames or sparks created by drill motors, welding equipment, etc.
3. Do not connect or disconnect a battery charger cable while the charger is turned on.
4. Only work in well-ventilated areas. Do not inhale fumes.
5. When connecting jumper cables, always connect the positive cable first. (This applies to negative ground vehicles only.)
6. Do not connect the negative cable to a disabled battery — connect it to an engine ground only.
7. Keep an acid neutralizer handy and ready for use. (A 50-50 solution of baking soda and water is one common type of acid neutralizer.)

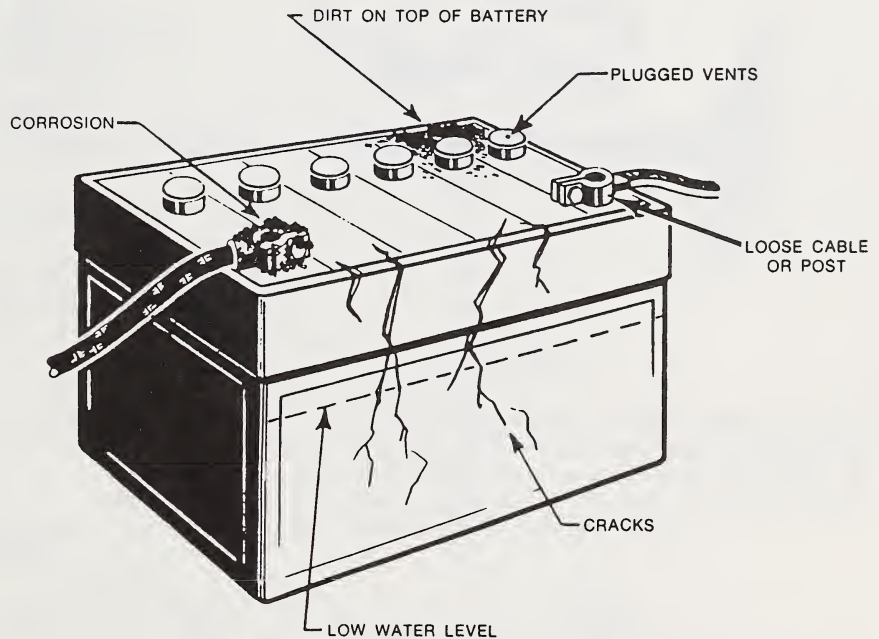
**7. Battery Preventative Maintenance**

A battery should be visually inspected at regular intervals, usually when other vehicle checks are being done (such as tire inspection, radiator water level, etc.). The following are items to look for:

1. Inspect the battery case for cracks or leaks. A leaking battery should be replaced. Before placing a new or used battery in a vehicle's battery box one should wash the battery box with a solution of water and baking soda. This will neutralize any acid that has leaked from the battery.
2. Inspect the battery posts, clamps, and cables for breakage, loose connections, or corrosion. Corroded battery cables should be removed from the battery and washed in a water-baking soda solution. When reconnected they should be coated with an anti-corrosion lubricant.
3. Check that the top of the battery is clean and dry. Any dirt or electrolyte on the battery top will cause excessive self-discharge.

4. Make sure that the battery box is solidly mounted and is in good condition. Check that the hold-down clamp firmly holds the battery in place. Also make sure that no bolts are protruding into the bottom of the battery box. Placing a thin sheet of plywood under the battery (in the battery box) is a good way to protect the battery case.
5. Inspect the battery for raised cell covers and/or a warped case. If in evidence this indicates the battery has been overheated and/or overcharged.
6. Do not store discharged storage batteries in freezing conditions. A discharged battery has a greater percentage of water in the electrolyte. Storing it in freezing temperatures would cause the electrolyte to freeze and damage the battery (e.g. crack the case).

Any problems found during the battery inspection should be attended to immediately.

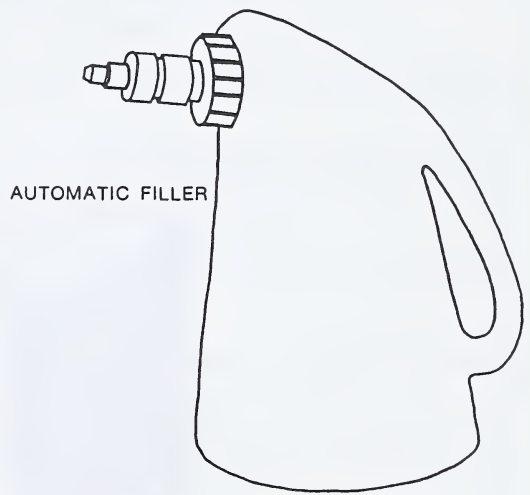
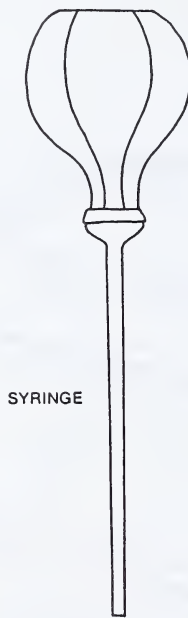


*Courtesy of British Columbia  
Department of Education*

(a) **Checking and adding water (non-maintenance free type batteries)**

Of the chemicals in a non-maintenance free type battery, water is the one chemical which has to be added. The usual recommended interval for checking a battery is every 30 hours or 1600 kilometers. In very warm weather checks should be done more frequently. If large amounts of condensation are seen on the battery top and a low electrolyte level is evident then this usually indicates an overcharging condition. If this continues after water has been added then the charging system will have to be checked.

Fill the battery cells with clean water (preferably distilled water) to the bottom of the fill hole. Any higher filling will cause unnecessary spillage. Use paper towels to dry the top of the battery when completed. Two types of battery fillers can be used to avoid spillage. They are shown below.



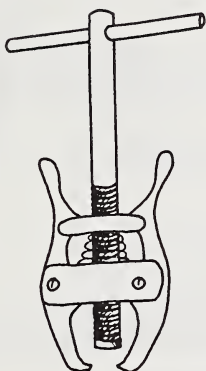
*Courtesy of British Columbia  
Department of Education*

*Courtesy of British Columbia  
Department of Education*

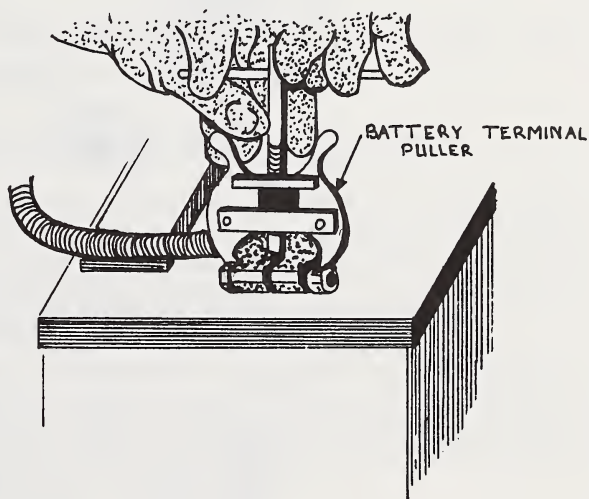
**(b) Removing, cleaning and installing batteries**

When removing or installing a battery follow these recommendations.

- (i) Disconnect the ground cable from the battery first. Use a terminal puller to remove the cables. Do not hammer on the battery posts or cables in order to loosen them. When reinstalling a battery connect the ground strap last.

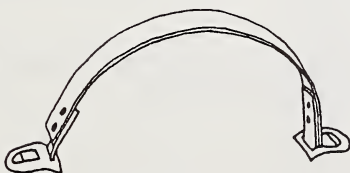


TERMINAL PULLER

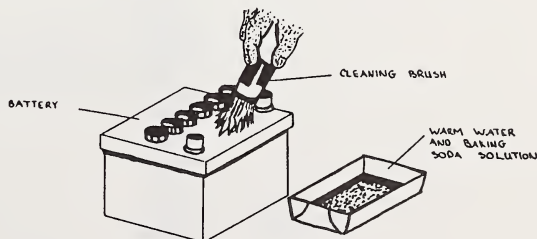


*Courtesy of British Columbia  
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- (ii) Remove the battery hold-down and/or clamps using the appropriate tools then carefully lift the battery from the battery box. For conventional batteries with lead posts, a carrying strap is the safest way of removing the battery. Be careful not to drop the battery since the case can easily crack. Keep the battery clear of clothing since the acid can eat through cloth.

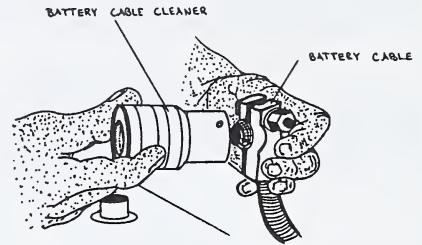
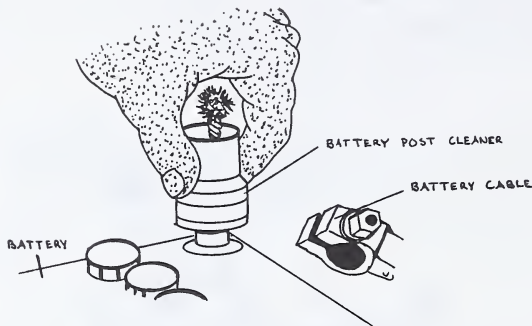


STRAP CARRIER

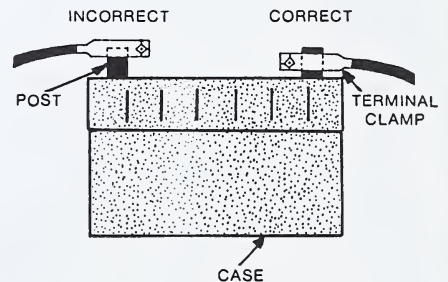
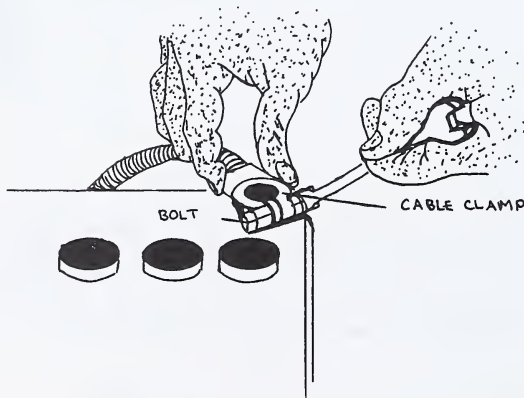


*Courtesy of British Columbia  
Department of Education*

- (iii) Clean the battery with a baking soda and water solution. Dry the battery. Clean the terminals using a terminal brush or scrape clean using a knife. Clean the battery cables similarly.



- (iv) When installing the battery be sure not to overtighten the bolts on the battery cable clamp or the hold-down. This could damage the clamps or crack the case.



*Courtesy of British Columbia  
Department of Education*

- (v) Coat the battery cables with an anti-corrosive agent such as grease or vaseline. An anti-corrosive spray may also be used.

## TESTING CONVENTIONAL BATTERIES

A battery must supply a flow of current and possess a voltage. Various tests can be carried out which will indicate how well the battery is doing its job. There are three tests which can be used on conventional batteries.

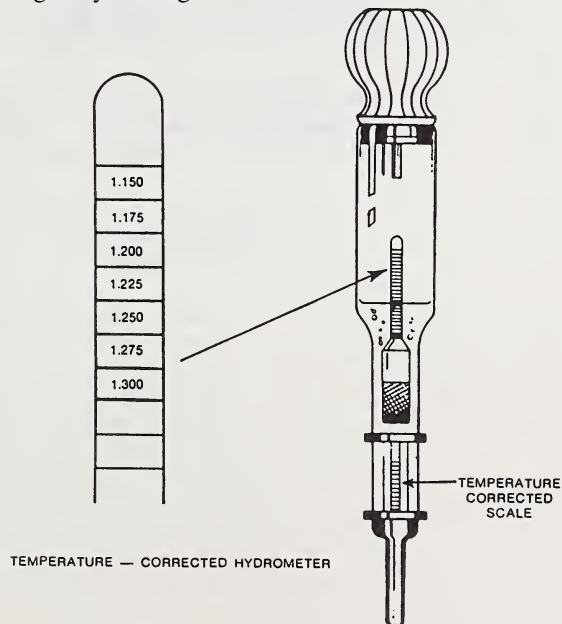
1. Hydrometer - tests specific gravity
2. Load test - capacity test
3. Three minute fast charge test

Not all of these tests have to be performed in order to give an analysis of a battery. Two tests are satisfactory to give an indication of the battery's condition.

### 1. The Hydrometer Test (also called Specific Gravity Test)

The battery hydrometer is used to test the specific gravity (relative density) of the electrolyte. Electrolyte is drawn into the glass tube using the squeeze bulb. As more electrolyte is drawn in, the float in the tube rises to a level of specific gravity. This level indicates the strength of the battery's charge. Better quality hydrometers have a thermometer built into them to give a temperature correcting factor for greater accuracy.

Hydrometers are the most common battery tester found in shops. Although a hydrometer can give an indication of a battery's condition, they can also give misleading results. For example, there could be a poor internal connection between the cells which prevents high current flow. Testing the battery cells using a hydrometer could indicate good specific gravity readings.



*Courtesy of British Columbia  
Department of Education*

When using the hydrometer to make a specific gravity test on a battery follow these steps:

- (a) Using the hydrometer's squeeze bulb, remove electrolyte from one cell until the float moves freely without touching the top or bottom. Hold the hydrometer vertically to prevent the float from touching the sides of the float tube.
- (b) With your eye level with the float take the float reading and record it.
- (c) Note the electrolyte temperature.

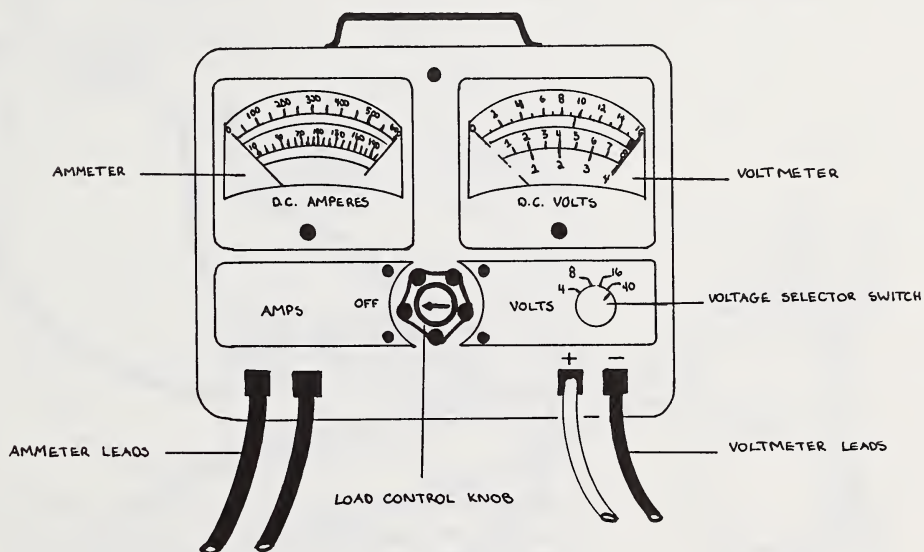
**Notes:**

- (i) If water has recently been added to the battery then the hydrometer will not give an accurate reading of the battery's state of charge.
- (ii) If the battery temperature is not  $27^{\circ}\text{C}$  then the specific gravity reading will have to be compensated using the following formula. This formula only applies to hydrometers which do not have a temperature corrected scale. Add four points (0.004) to the specific gravity measurement of the float reading for each  $5^{\circ}\text{C}$  above  $27^{\circ}\text{C}$  or subtract four points (0.004) from the float reading for each  $5^{\circ}\text{C}$  below  $27^{\circ}\text{C}$ .
- (iii) Repeat the tests (steps a, b, and c) on all the remaining battery cells.
- (iv) Compare each cell's specific gravity reading and note the amount of difference. All cell readings should be within thirty points (0.030). If the difference is greater than thirty points an unsatisfactory condition exists in the battery and further tests should be done.
- (v) Determine the battery's state of charge by locating its specific gravity on the Charge Table shown below. Typical values are shown but students should be aware that specific gravity readings vary in different types of batteries.

SPECIFIC GRAVITY READINGS	BATTERY CONDITION
1.265 - 1.290	Fully charged
1.250 - 1.265	Three-quarters charged
1.225 - 1.250	One-half
1.200 - 1.225	One-quarter charged
1.175 - 1.200	Barely operative
1.110 - 1.175	Discharged

## 2. The Load Test (or Capacity Test)

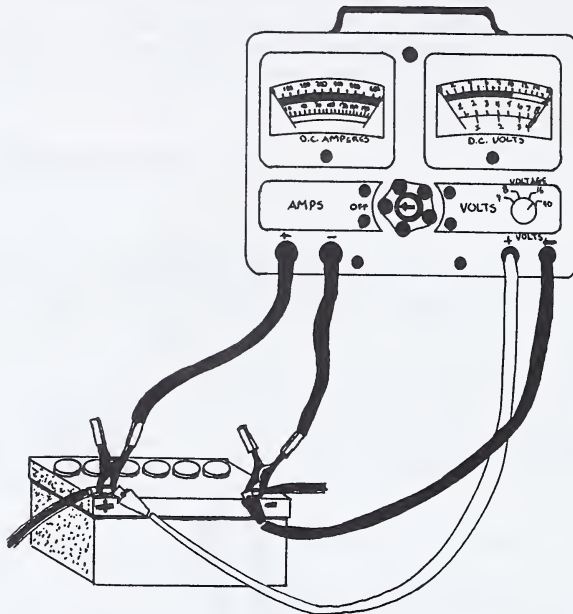
A battery load tester (or battery starter tester) gives the best indication of a battery's condition. If the specific gravity of each cell of battery is 1.225 or higher, then a load test (also known as a capacity test) can be done on the battery. If the specific gravity of any cell is less than 1.225 then a test called a light load test (which tests each cell) will have to be done. A typical battery load tester is shown below.



BATTERY STARTER TESTER

When making a load test on a battery follow these instructions.

- (a) Connect the tester's ammeter and voltmeter leads as shown below.



- (b) Turn the testers Load Control Knobs clockwise until the Ammeter reads exactly three times the Ampere Hour Rating of the battery (for example, for an 80 AH battery the meter should read 240 amperes).
- (c) Maintain the load for 15 seconds then note the voltmeter reading. Turn the Control Knob to the Off position.

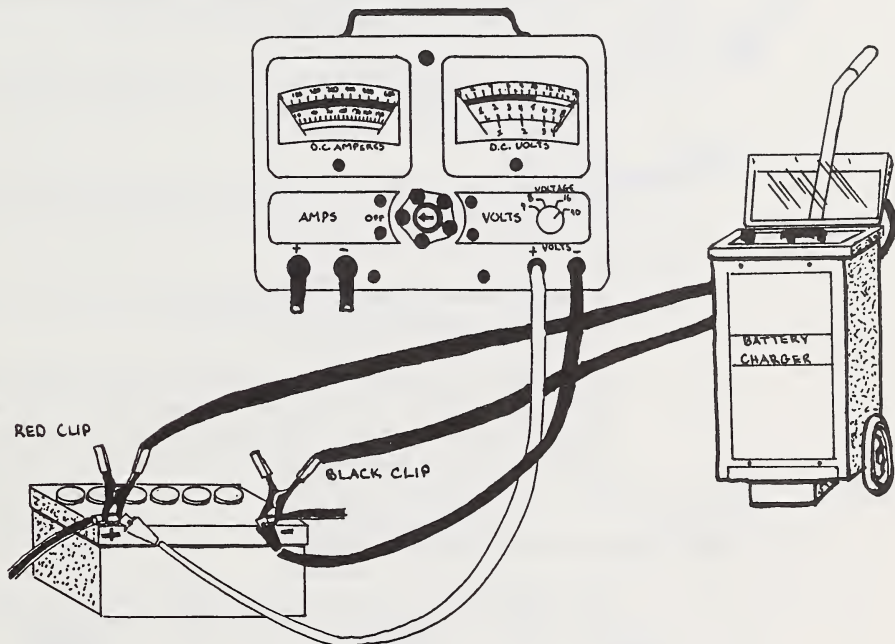
If the voltmeter reading is within the green band (9.6 volts or higher for a 12 volt battery) then the battery has a good output capacity. The battery, however, may require some charging to bring it up to peak performance.

### 3. The Three Minute Fast Charge Test

The three minute fast charge test is done on a battery which is very low or dead (one that has failed the load test). Performing a three minute fast charge test on a battery which has a full charge or nearly a full charge will give a false reading. This test indicates whether the battery will accept a charge and uses equipment which is found in most shops (a fast charger plus an accurate voltmeter).

The procedures to be followed when performing a three minute fast charge test are:

- (a) Connect the charger and voltmeter as shown below.



- (b) Adjust the charging switch to obtain a charging rate of about 40 amperes (for a 12 volt battery).
- (c) After three minutes, while the charger is still operating on fast charge, observe the voltmeter reading. If the reading is beyond the green band (or exceeds 15.5 volts on a 12 volt battery), the battery is sulphated (or worn out) and should be replaced.

### **5. Summary of Testing Procedure for Conventional Batteries**

- (a) Take a specific gravity reading of each cell and note the result. No more than a 0.030 point difference is allowed between cells.
- (b) If the specific gravity readings are 1.225 or higher then do a load test. At the end of 15 seconds the voltage should not be less than 9.6 volts for a 12 volt battery (or 4.8 volts for a 6 volt battery).

If a battery passes these two tests then it is considered satisfactory for use. A battery which fails the load test should have a three minute fast charge test done on it to see if it will take a charge.

- (c) If the electrolyte is too low for a measurement and water is added to the cells then a light load test may be performed.
- (c) If the battery is low or dead then perform a three minute fast charge test on it. If the voltage does not exceed the maximum limit (from fast charge instruction manual) then the battery is considered satisfactory. If the voltage exceeds the maximum limit in three minutes then the battery is sulphated (no good).

### **6. Maintenance Free Battery Testing**

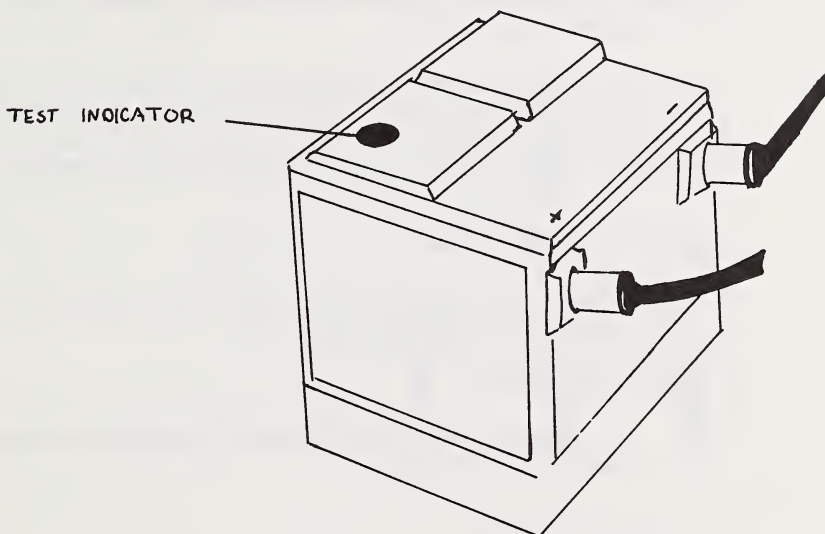
In a maintenance free battery the electrolyte is sealed into the battery. Therefore, a specific gravity test cannot be used. A load test is the test used for maintenance free batteries.

The specific type of load test procedure to be followed varies depending on the manufacturer of the maintenance free battery. Generally, though, the procedure follows that as stated below:

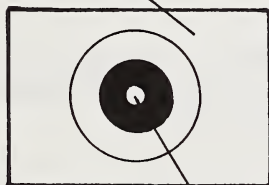
- (a) Connect the voltmeter and specified load across the terminals of the battery.
- (b) After 15 seconds, with the load connected, read the voltage. Disconnect the load.
- (c) If the minimum voltage is 9.6 volts or more then the battery is good but if less than 9.6 volts then replace the battery.

**Note:** The reading of 9.6 volts is made at a temperature of 21°C or above. At lower temperatures this minimum voltage will be reduced. For example, at 4°C the minimum voltage is 9.3 V.

Some maintenance free batteries have a test indicator at the top of the battery case as shown below. This test indicator can be used as a rough guide to indicate the battery charge.

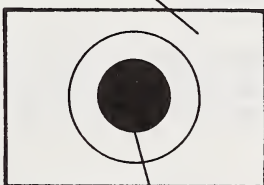


BATTERY CHARGE  
OK, FLUID LEVEL OK:  
BATTERY TOP



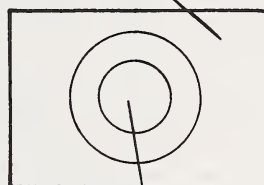
DARKENED INDICATOR  
WITH GREEN DOT

BATTERY CHARGE \*  
LOW, FLUID LEVEL OK:  
BATTERY TOP



DARKENED INDICATOR  
NO GREEN DOT

BATTERY CHARGE UNKNOWN,  
FLUID LEVEL LOW  
BATTERY TOP



LIGHT OR BRIGHT  
INDICATOR, NO GREEN DOT

CAN BE JUMP STARTED,  
TESTED OR CHARGED

DO NOT JUMP START,  
TEST OR CHARGE

\* CHARGE MAY STILL BE SUFFICIENT TO START VEHICLE

## CHARGING BATTERIES

When an engine is running, the battery is charged by an alternator or generator. However, over time the battery charge wears down to where it will not start the engine. When a battery's charge state is low then it should be recharged. The recharging can be done either in the vehicle or the battery can be removed.

While there are a great number of different battery chargers available, the most common type is a constant voltage charger.

This type of charger supplies the battery with a constant voltage while being charged. For a 12 volt battery approximately 15 volts will be applied. This type of charger will charge the battery at a high amperage rate initially and as the battery charge builds up the amperage rate decreases. When the battery becomes fully charged the amperage rate is near zero.

### 1. Battery Charger Types

Battery chargers can be slow chargers, fast chargers, trickle chargers, or a combination of any of the above.

#### (a) Slow Chargers

Slow chargers are used to completely recharge a dead battery. This procedure can take up to 48 hours.

#### (b) Fast Chargers

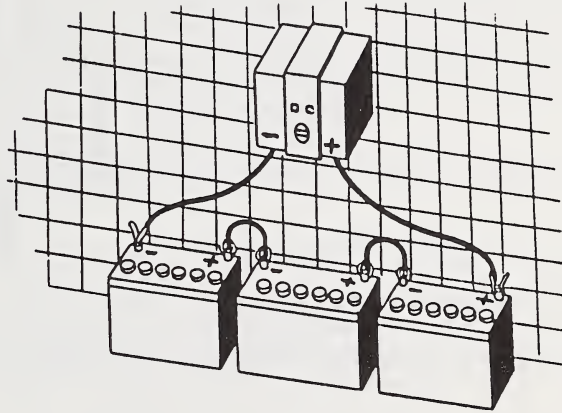
Fast chargers are used for a quick boost, usually not taking more than 1 hour. Fast chargers do not do as complete a job as slow chargers. Fast chargers usually have the ability to provide a slow charge as well.

#### (c) Trickle Chargers

Trickle chargers are used to keep a battery up to full charge. They are especially good for batteries that are used very little or for wet charged batteries being stored. Most trickle chargers are of the constant voltage type.

## 2. Charging Conventional Batteries

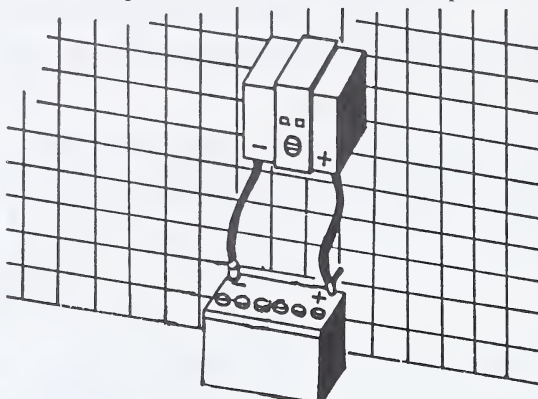
Time is usually the main factor to consider when determining whether to fast charge or slow charge a battery. Slow charging a battery is better since more complete charging is done on the battery plates. In fast charging the charging takes place only on the surface of the battery plates. However, most times people do not have the 20 to 50 hours required to do a slow charge on a battery and hence fast charges have to be done.



*Courtesy of John Deere Ltd.*

**(a) The Constant Voltage Slow Charger**

Constant voltage chargers are connected to the battery in parallel as shown below. The charger's black (negative) lead is connected to the negative post of the battery and the red (positive) lead is connected to the positive lead of the battery.



*Courtesy of John Deer Ltd.*

Some chargers are constructed so they may charge more than one battery at a time. The maximum number of batteries the charger can charge is indicated on the charger case. Small home style chargers can only charge one battery.

The charge rate is automatically set by the charger. The rate will initially be high and decrease as the battery becomes charged.

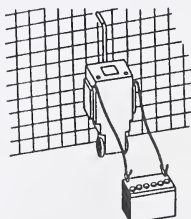
The specific gravity of the cells should be checked occasionally and when fully charged the batteries should be disconnected from the chargers.

**(b) Fast Chargers**

As was previously indicated, fast chargers give a high rate of charge for a short period of time (usually 1 hour maximum). While slow chargers are usually fixed in position (mounted on a wall or bolted to a table) fast chargers are usually portable in nature so they can charge the battery while it is in a vehicle. Fast chargers, in most cases, charge only one battery at a time.

When fast charging a battery two characteristics should be watched for. These are:

- (i) Never allow the electrolyte temperature to exceed  $51^{\circ}\text{C}$ . Overheating drastically shortens the life of a battery. Overheating is usually the result of overcharging so if the temperature approaches  $51^{\circ}\text{C}$  remove the battery from the charger.



*Courtesy of John Deer Ltd.*

- (ii) As a battery ages the electrolyte will become discoloured by sediment. During fast charging the sediment is stirred up and gets trapped between the plates which can cause a short to occur. If discolouring occurs then lower the charge rate to prevent a short from occurring.

### **3. Charging Maintenance Free Batteries**

The procedure used for charging maintenance free batteries is very similar to that followed in charging conventional batteries. Conventional battery charging equipment is used but the charging times are different for maintenance free batteries. As well, the charging rate for maintenance free batteries is less than that for conventional batteries when slow charging. When fast charging maintenance free batteries the charging rate is greater than that for conventional batteries.

Follow these rules when charging maintenance free batteries which have a test indicator.

- (a) Do not charge a battery if the green dot is visible.
- (b) Do not charge a battery if the test indicator is light yellow in colour.
- (c) Stop charging when the green dot appears or when the maximum charge rate is reached.

### **4. Summary of Safe Battery Charging Practices**

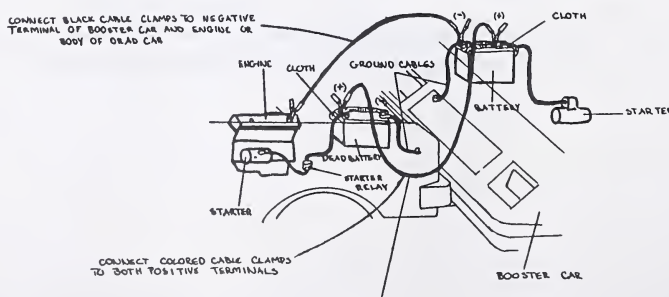
- (a) Before charging conventional batteries make sure that the battery tops are clean, the electrolyte is up to the correct level, and the vent caps are loosened or removed to allow any gases formed during charging to escape.
- (b) All battery chargers, whether fast or slow chargers, need to be supplied with 110 volts alternating current.
- (c) Always make sure a charger is turned off when connecting the charging cables to a battery.
- (d) Turn off all electrical accessories in a vehicle when charging a battery while it is in the vehicle.
- (e) Disconnect a vehicle's battery cables from the battery before charging the battery in the vehicle. (The vehicle's alternator can be damaged.)
- (f) Make sure all connections are solidly attached before turning on the charger.
- (g) When connecting any charger make sure that the connection polarity is observed. This is negative connects to negative and positive connects to positive.

- (h) Since many types of battery chargers are available, always follow equipment manufacturer's instructions for hookup and charging rates.
- (i) Switch off the battery charger before disconnecting the charger leads. This will prevent any sparks occurring which may ignite the hydrogen gas produced during charging.
- (j) Never charge a battery in a location where sparks may occur (such as near welding, grinding, or electric motors).
- (k) Use the hydrometer's thermometer to check that the electrolyte temperature does not exceed  $51^{\circ}\text{C}$  on maintenance free batteries feel the bottom of the case. If it is hot disconnect the charger or reduce the charge rate.
- (l) Upon completion of charging a battery make sure to check the electrolyte level in each cell, where possible.

## 5. Jumper Cables

When a vehicle has a dead battery it is a common practice to start the vehicle using another vehicle's battery and a set of jumper cables. Observe the following practices when doing this.

- (a) Make sure all the vehicle accessories (lights, radio, etc.) are off before connecting the cables.
- (b) Make sure to jump the dead battery using another battery of the same voltage. For example, use a 12 volt battery to jump a 12 volt battery. Using a 12 volt battery to jump a 6 volt battery can cause electrical arcing and the possibility of fire or explosion.
- (c) Observe polarity when jumping. Connect the jumper cables so that negative is connected to negative and positive is connected to positive.
- (d) Connect the cables in this order (for negative ground vehicles)
  - (i) Connect one cable clamp to the positive terminal of the dead battery and then connect the other end to the positive terminal of the booster battery.
  - (ii) Connect the second clamp to the negative terminal of the booster battery. Attach the other end of the clamp to a good ground (such as an unpainted bolt or bracket) on the engine or chassis of the car being boosted. This connection may cause a spark so pick a ground connection far from the dead battery's negative terminal. A diagram of proper connections is shown below.



- (e) Never use a fast charger as a booster battery in order to start an engine.
- (f) Maintenance free batteries can have jumping procedures which differ from conventional batteries. Check the manufacturer's recommendations.
- (g) Jumper cables should be the shortest possible length since the longer the length of cable used the greater the voltage drops.
- (h) Make sure the jumper cable clamps are solidly affixed to the battery terminals to ensure good connections.

Answer the following Self-Correcting exercises. Check your answers with those listed at the end of this lesson.

### SELF-CORRECTING EXERCISE 1: Basic Electrical Theory

Write the letter of the correct answer in the space provided to the left of each question.

- \_\_\_\_\_ 1. In a conductor electricity flows in the direction
  - (a) positive to negative.
  - (b) positive to neutral.
  - (c) neutral to negative.
  - (d) negative to positive.
  
- \_\_\_\_\_ 2. Electricity is a form of
  - (a) magnetism.
  - (b) energy.
  - (c) light.
  - (d) heat.
  
- \_\_\_\_\_ 3. A flow of electrical current is caused by the movement of
  - (a) protons.
  - (b) atoms.
  - (c) neutrons.
  - (d) electrons.
  
- \_\_\_\_\_ 4. The basic unit of resistance is
  - (a) the volt.
  - (b) the ohm.
  - (c) the resistance.
  - (d) amperes per volt.

**SELF-CORRECTING EXERCISE 2: Storage Batteries**

- \_\_\_\_\_ 1. How many cells are there in a 6 V wet cell battery?
- (a) 1
  - (b) 3
  - (c) 6
  - (d) 12
- \_\_\_\_\_ 2. Is the positive post of a conventional battery larger or smaller than the negative post?
- (a) larger
  - (b) smaller
  - (c) the same size
  - (d) depends on individual manufacturers
- \_\_\_\_\_ 3. When a charged battery is suddenly discharged the electrolyte has an increased percentage of
- (a) sulphur.
  - (b) sulphuric acid.
  - (c) water.
  - (d) hydrogen.
- \_\_\_\_\_ 4. If you replaced a 12 V 40 Ah battery in a Volkswagen with a 12 V 130 Ah battery from a Caterpillar diesel, would you burn out the Volkswagen's wiring?
- (a) Yes
  - (b) No
  - (c) only if the battery is overcharged
  - (d) it depends on the temperature of the electrolyte
- \_\_\_\_\_ 5. Spilled battery electrolyte can be neutralized using
- (a) distilled water.
  - (b) sulphuric acid.
  - (c) baking soda.
  - (d) lead peroxide.
- \_\_\_\_\_ 6. To prevent corrosion and bad connections when installing battery cables to battery terminals one should
- (a) make sure they are clean and dry.
  - (b) make sure they are tight.
  - (c) coat the connections with grease.
  - (d) do all of the above.

**SELF-CORRECTING EXERCISE 3: Battery Testing and Charging**

- \_\_\_\_\_ 1. A hydrometer tests the
- (a) battery voltage.
  - (b) battery current.
  - (c) battery cells.
  - (d) battery resistance.
- \_\_\_\_\_ 2. The first step in checking the relative density of a battery cell in a conventional battery is to
- (a) add water.
  - (b) charge it.
  - (c) clean the cables.
  - (d) open the vent plugs.
- \_\_\_\_\_ 3. While battery relative density is only a general indication of the battery state of charge, a battery with a reading of about 1.222 per cell could be said to be
- (a) half charged.
  - (b) fully charged.
  - (c) three-quarter charged.
  - (d) discharged.
- \_\_\_\_\_ 4. As the discharge rate of a battery goes up, the
- (a) amperage goes down.
  - (b) voltage goes up.
  - (c) temperature goes down.
  - (d) voltage goes down.
- \_\_\_\_\_ 5. When disconnecting a battery always
- (a) remove the filler caps first.
  - (b) remove the ground cable first.
  - (c) remove the positive cable first.
  - (d) first clean the battery.
- \_\_\_\_\_ 6. A battery with a relative density reading of 1.290 volts per cell is
- (a) fully charged.
  - (b) half charged.
  - (c) discharged.
  - (d) quarter charged.

- \_\_\_\_\_ 7. When testing the specific gravity of a conventional battery, the variation between cells should not exceed
- (a) 0.010
  - (b) 0.030
  - (c) 0.060
  - (d) 0.300
- \_\_\_\_\_ 8. When charging a lead-acid battery what kind of gases are given off by the charging process?
- (a) oxygen
  - (b) hydrogen
  - (c) nitrogen
  - (d) carbon dioxide
- \_\_\_\_\_ 9. Before connecting a charger to a battery to be charged one should
- (a) plug in the charger to an AC power source.
  - (b) remove the battery vent plugs.
  - (c) make sure the charger is switched off.
  - (d) make sure the cells are topped off with mineral water.
- \_\_\_\_\_ 10. In a load test, if all cells read below 1.60 volts, the battery
- (a) is defective.
  - (b) is in need of water.
  - (c) is in need of charging.
  - (d) should have a three-minute fast charge test done.

Complete the following exercises and send them in for correction.

## EXERCISE 1: Ohm's Law and Basic Circuit Theory

1. An automobile uses a twelve volt battery and the circuit you are testing has a resistance of eight thousandths of an ohm. What is the amperage? Show all your work.
2. An electrical unit in this same car uses fifteen hundred amperes when operating. What is the maximum that the resistance can be? Show all work.

**EXERCISE 2: Batteries and Charging**

1. What three factors affect the amount of current a storage battery can produce?
  - (a) \_\_\_\_\_
  - (b) \_\_\_\_\_
  - (c) \_\_\_\_\_
  
2. Why are there no vent plugs in a maintenance free battery?  
\_\_\_\_\_  
\_\_\_\_\_
  
3. Is it safe to leave a storage battery discharged during freezing weather? Why or why not?  
\_\_\_\_\_  
\_\_\_\_\_
  
4. When selecting a new battery for a vehicle, one should make sure the cold power rating will match \_\_\_\_\_  
\_\_\_\_\_
  
5. When fast charging a battery what two important things should be watched out for?
  - (a) \_\_\_\_\_  
\_\_\_\_\_
  - (b) \_\_\_\_\_  
\_\_\_\_\_
  
6. Does a fast charger or a slow charger do a better job of charging a battery? Why?  
\_\_\_\_\_  
\_\_\_\_\_

**ANSWERS TO SELF-CORRECTING EXERCISES****Self-Correcting Exercise 1**

- |               |               |
|---------------|---------------|
| 1. d (page 3) | 3. d (page 3) |
| 2. b (page 4) | 4. b (page 5) |

**Self-Correcting Exercise 2**

- |                    |                    |
|--------------------|--------------------|
| 1. b (page 18)     | 4. b (page 23)     |
| 2. a (page 18)     | 5. c (page 24)     |
| 3. c (pages 19-20) | 6. d (pages 24-25) |

**Self-Correcting Exercise 3**

- |   |                     |
|---|---------------------|
| 1. c (page 29)  |                     |
| 2. d (page 30 — To test the electrolyte in each cell you must first remove the vent plugs.) |                     |
| 3. a (page 30 — A reading of 1.222 is closer to being half-charged than being discharged.)  |                     |
| 4. d (page 20)  |                     |
| 5. b (page 27)  | 8. b (page 40)      |
| 6. a (page 30)  | 9. c (page 24)      |
| 7. b (page 30)  | 10. d (pages 33-34) |



# LESSON RECORD FORM

1746 Mechanics 12  
Module 2

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(If label is missing  
or incorrect)

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Time Spent on Lesson

Lesson Number

## Student's Questions and Comments

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- (1) All pages are numbered and in order, and no paper clips or staples are used.
- (2) All exercises are completed. If not, explain why.
- (3) Your work has been re-read to ensure accuracy in spelling and lesson details.
- (4) The Lesson Record Form is filled out and the correct lesson label is attached.
- (5) This mailing sheet is placed on the lesson.

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## VEHICLE CHARGING SYSTEMS

Introduction  
Charging Circuits  
DC Circuits  
AC Circuits

### INTRODUCTION

A vehicle requires a charging circuit in order to generate current which is required to recharge the battery and also operate electrical accessories such as a radio. There are two types of charging circuits in use on vehicles. These are:

1. Direct current (DC) charging circuits in which a generator is used to produce the current, and
2. Alternating current (AC) charging circuits in which an alternator is used to produce the current.

As mentioned in the last lesson all vehicle charging circuits work in three ways.

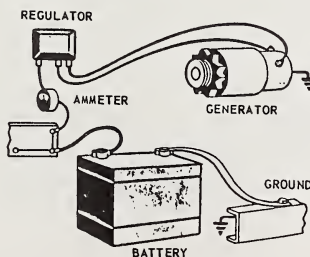
1. During initial starting of a vehicle the battery provides all the required current.
2. During low speed or idle operation the battery helps the generator/alternator unit to supply current.
3. During high speed or normal operation the generator/alternator unit supplies all current and recharges the battery.

In both AC and DC charging circuits it is the battery which supplies current to start the engine. Once started the engine is used to turn the generator/alternator unit which provides the current to power such accessories as lights, ignition, etc. As well the battery will provide extra current when the generator/alternator unit cannot provide enough on its own (during heavy load periods).

### CHARGING CIRCUITS

#### 1. DC Charging Circuits

A typical DC charging circuit of a vehicle is shown below.



*Courtesy of John Deere Ltd.*

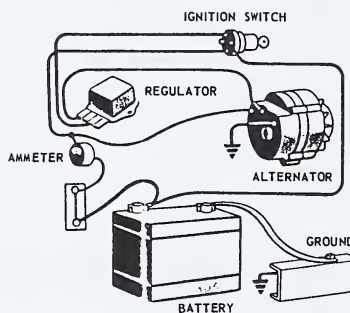
In this situation the engine powers a generator which is used to produce alternating current. Remember that alternating current moves in one direction and then reverses to go in the opposite direction. More information on this will be discussed later in this lesson. The commutator and brushes, which are enclosed inside the generator, change the alternating current to direct current (direct current moves in one direction).

Current from the generator goes through a regulator. The regulator performs three functions.

- (a) It prevents overcharging of the battery.
- (b) It controls the generator's output current to a safe amount.
- (c) It opens and closes the charging circuit between the generator and battery.

## 2. AC Charging Circuits

In an AC charging circuit an alternator rather than a generator is used to produce current. A typical AC charging circuit is shown below.



*Courtesy of John Deere Ltd.*

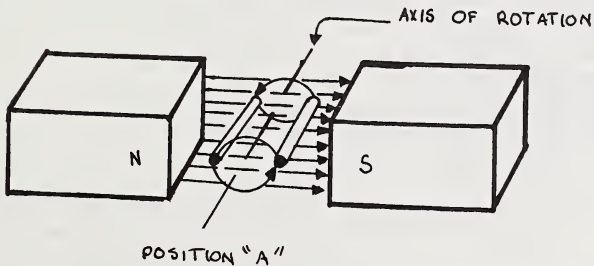
While both an alternator and generator are similar in that they both produce current, the alternator differs in the way it produces that current. Alternators use electronic devices called diodes to change AC to DC rather than the commutator and brushes used in a generator.

The regulator is used to prevent overcharging of the battery and to also limit the alternator's voltage output to a safe amount. Most modern regulators are of the solid state type as they use various modern electronic components (transistors, integrated circuits, etc.).

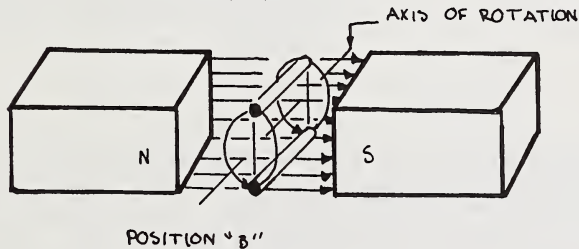
## DC Circuits

## 1. Generators

As you saw in the previous lesson, whenever a conductor is moved at right angles to the lines of force, a voltage will be generated in the wire. This causes a current to flow through the wire and hence the external circuit. No voltage is produced in the conductor when it is moved parallel to the lines of force. This is because no lines of the force are being cut by the conductor. When this conductor cuts the lines of force while moving in one direction, it generates the flow in a given direction. If the conductor cuts the field in the reverse direction, then the flow will go in the opposite direction also. Refer to the four diagrams on page 14 of lesson seven. To summarize this we can say that, when a conductor is moving perpendicular to the lines of force it generates maximum voltage, but when it is parallel to such lines of force it generates **no** voltage.



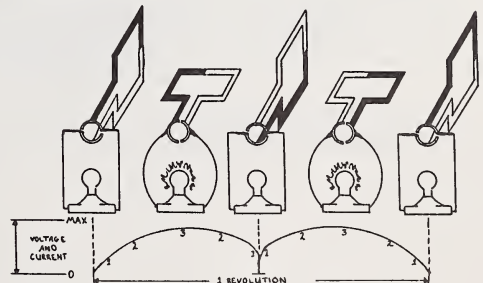
The rotating coil is at this moment producing maximum current and voltage. It is breaking the maximum number of lines of force while moving perpendicular to the lines of magnetic force.



No current and therefore no voltage is being produced. No lines of force are being broken as the conductor is moving parallel to the lines of magnetic force.

During rotation of a conductor from the parallel to the right angle position (going from positions B to A) the number of lines of force cut changes. This change is a gradual increase from zero to a maximum. Likewise when the conductor makes a second quarter turn it goes from cutting a maximum number of force lines to again cutting none.

The drawing below shows the rise and fall of voltage and current during one revolution if there is only one armature coil and two commutator segments. Note how the brightness of the bulb varies at different positions.



At position 1 the light is off.  
 At position 2 the light is half brightness.  
 At position 3 the light is full brightness.

Notice how the number of lines cut rises from zero to a maximum and then back to zero in each one half of a revolution. Voltage and therefore current will also rise and fall in the same manner. This rise and fall occurs endlessly during all of the half revolutions through which the conductor is rotated.

In the following diagram we will apply these principles to a simple direct current generator with only one armature coil. In the diagram there are the same magnetic poles and the same armature conductor as has been used before. More necessary details have been added, however.

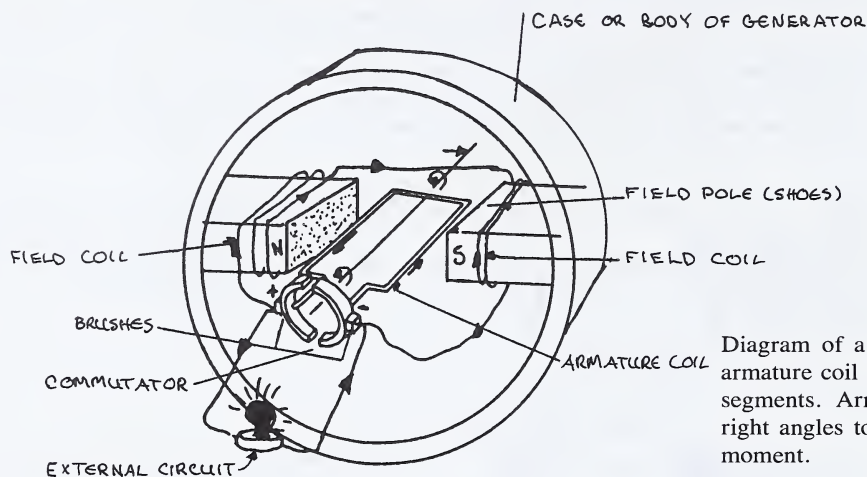


Diagram of a generator with only one armature coil and only two commutator segments. Armature coil is moving at right angles to the lines of force at the moment.

The single armature coil is located in the slots of a cylindrical piece of soft steel called the armature core (not shown). The ends of the coil are soldered to semicircular segments of copper to form that we call the "commutator." The two pieces are insulated from each other. Two "brushes" are pressed against this commutator. This provides a sliding electrical contact. As the commutator and armature are rotated the brushes stay stationary and supply the pick up and deposit points for the electrons of the external circuit.

The magnetic field is produced electrically by coils of wire wound around iron cores called "field poles" (these are actually solenoids with iron cores, but they are called field coils and field poles). These two coils are in series (called series wound) and connected to the two brushes.

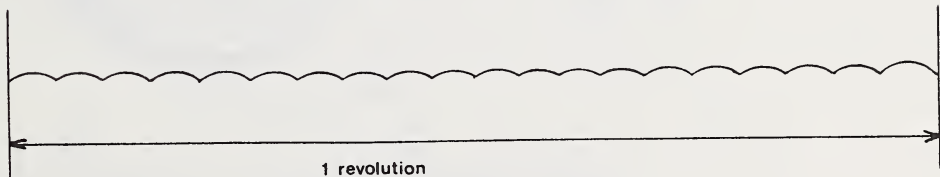
As can be seen in the previous diagram, the field coils and the external circuit are connected in parallel. Some current goes through the field coils and some through the external circuit. In reality only about 15% of the current produced by the armature goes to the field, while the balance is fed into the external circuit.

When this field circuit is in parallel with the external circuit, the device is known as a “shunt” generator. This is because some of the current produced is shunted into the field circuit.

When the generator is running, the magnetic lines of force produced by the armature and the magnetic lines of force produced by the field coils attract each other and try to prevent the armature from turning. Therefore, engine power is used to pull apart or break these lines of force in order to drive the generator. This attraction is similar to that discussed in the section on simple bar magnets in lesson 7.

The current flows out into the external circuit through the negative brush and returns through the positive brush to complete the circuit. One half revolution later the right and left hand sides of the armature coil have changed places. But so have the two segments, therefore, the current continues to flow in the same direction. This is why we call this device a DC generator, although in reality it does produce AC internally.

To level out this delivery of current (maximum to zero) that we get with one armature coil, we increase the number of coils. The drawing below shows that we get an almost smooth flow of current and voltage if 20 armature coils are used.



Instead of a pulsating current we have therefore attained the smooth current flow which is desirable. There are two serious practical objections to using a 20 coil armature. First, only one or two coils have commutators in contact with the brushes but many of the other coils are cutting force lines and producing voltage. This voltage has no place to go. Secondly, when the commutator bars of a particular coil break the brush contact, there is considerable arcing of the current. The arcing results from the fact that when contact is broken the armature is producing maximum voltage. Excessive commutator burning results.

Both of these problems have been satisfactorily solved by connecting the coils to adjacent commutator bars. This has been done by making the brushes thicker than the width of the commutator bars. Therefore, a brush makes contact with a new bar before it breaks the circuit of the preceding bar. This then eliminates both problems. (Note that in an actual generator each coil, instead of having one turn, has eight or more in order to increase the voltage and current output.)

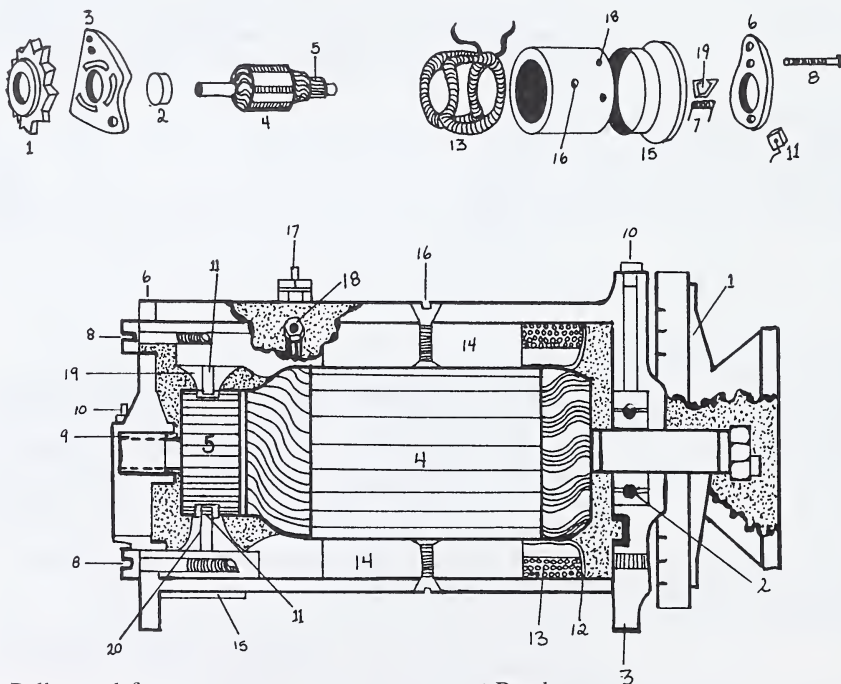
The armature is a conducting coil of wires which cuts the magnetic lines of force to produce a current. The size of the current depends on the number of turns in each coil.

## 2. Multiple Brush Generators

The shunt generator mentioned earlier can have two, four, or more brushes, but those on passenger vehicles usually only use two. These generators have no internal means of control (of voltage and current) and must rely on externally mounted voltage and current regulators. It will not be necessary here to go into four brush or other multiple brush generators because their principle of operation and regulation is the same as for the two brush generator.

## 3. Two-brush Generator Construction

The generator is normally mounted on the front of the engine and driven by a V-belt which also operates the fan and water pump. The principal parts of a typical generator are as follows:

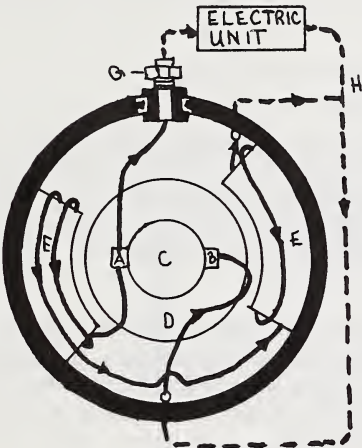


- 1. Pulley and fan
- 2. Ball bearing
- 3. Drive end frame
- 4. Armature
- 5. Commutator
- 6. Commutator end frame
- 7. Spring
- 8. Thru bolt
- 9. Bushing
- 10. Oiler

- 11. Brush
- 12. Insulation
- 13. Field coil
- 14. Pole shoe
- 15. Dust shield
- 16. Pole shoe screw
- 17. Armature terminal
- 18. Field terminal
- 19. Insulated brush holder
- 20. Grounded brush holder

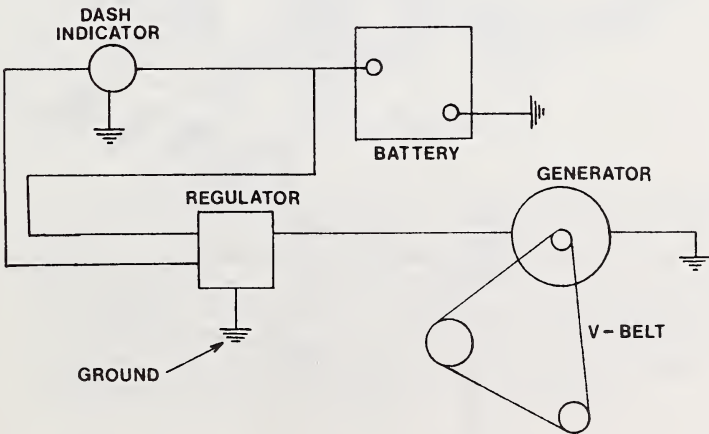
The drawing below shows the generator circuit in a simple form. The current produced in the armature is delivered to the brushes. Most of this current is sent to the external circuit by way of the armature terminal. A small percentage is diverted (shunted) to the field coils to maintain the magnetic field strength. The arrows depict the flow of the current.

Simple diagram of current flow in a shunt generator



- A- insulated brush
- B- grounded brush
- C- commutator
- D- armature
- E- pole shoes
- F- field frame
- G- insulated armature terminal
- H- ground circuit

A simplified block diagram of the charging system is shown below.



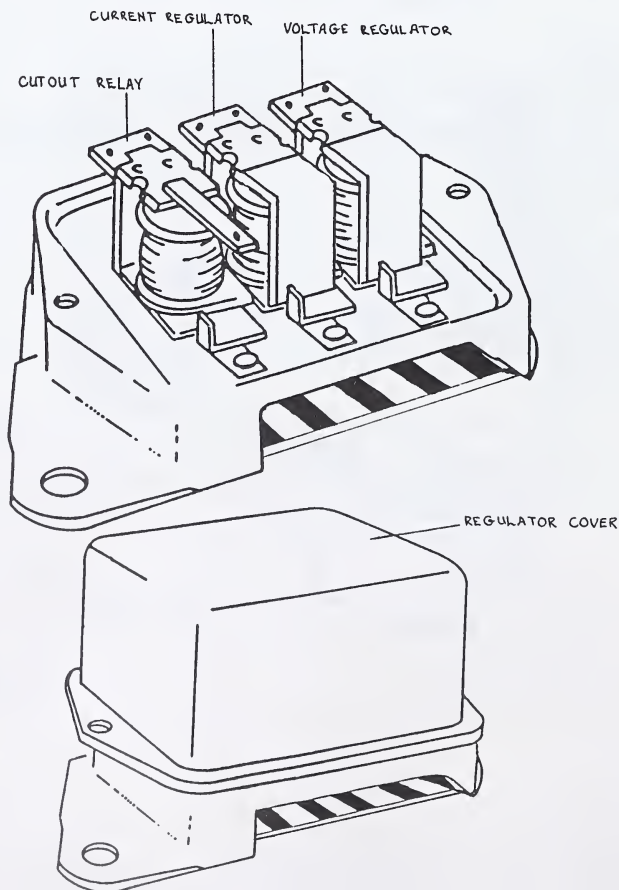
The field frame of a generator is a cylindrical tube usually made of steel. The commutator end frame and the drive end frame are also steel and held together by two long thru bolts. There are usually small dowels on the ends of the main tube for ensuring that the end plates are centered properly. The pole shoes are attached to the tube by heavy screws.

The armature shaft is mounted in ball bearings at the drive end and in a bushing at the commutator end. There is a cooling fan attached to the drive pulley to draw air through the generator to help dissipate the heat which it generates.

#### 4. The Generator Regulator

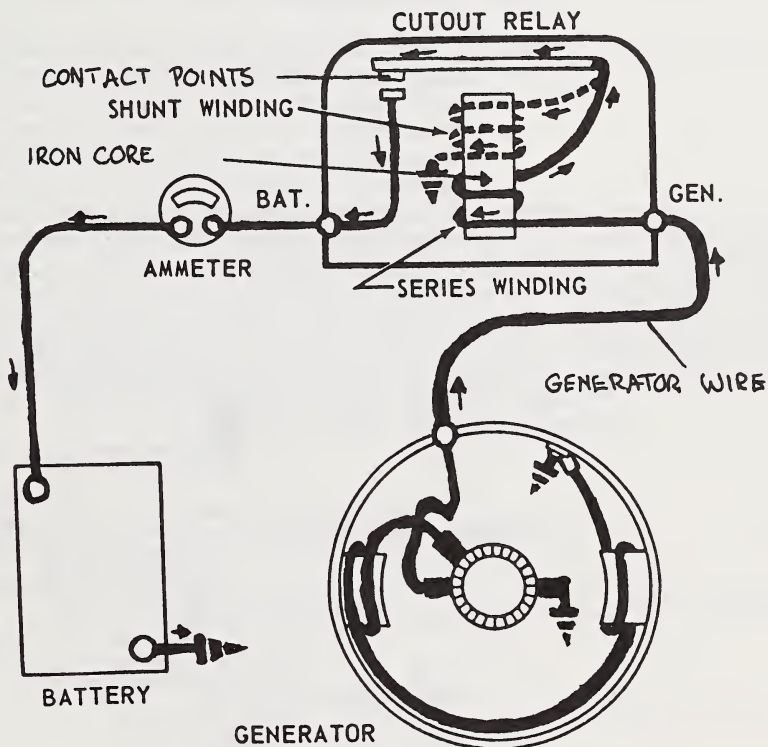
The generator type regulator has but one purpose and that is to regulate or control the charging rate (amount of voltage and current) in the generator-battery circuit. When a good battery is low, the regulator will automatically increase the charging rate. When the battery is charged, the regulator will cut down the charging rate to the battery and route the current to the operation of those electrical units in use so that no power is drained from the battery.

In a generator-based system, a modern regulator will consist of three basic units, a cut out relay, current regulator, and voltage regulator. In reality, each of these three units are simple solenoids with iron cores which interrupt the circuits automatically. A drawing of a typical regulator with the three basic units is shown below.



## (a) Cut out relay

The cutout relay opens the circuit to prevent the battery from discharging to ground through the generator whenever the engine is stopped, or the generator is operating at such a slow speed that its voltage output is less than the voltage output of the battery. Whenever the voltage output is greater from the generator than from the battery the relay closes the circuit so that the generator can furnish the current to the electrical system.



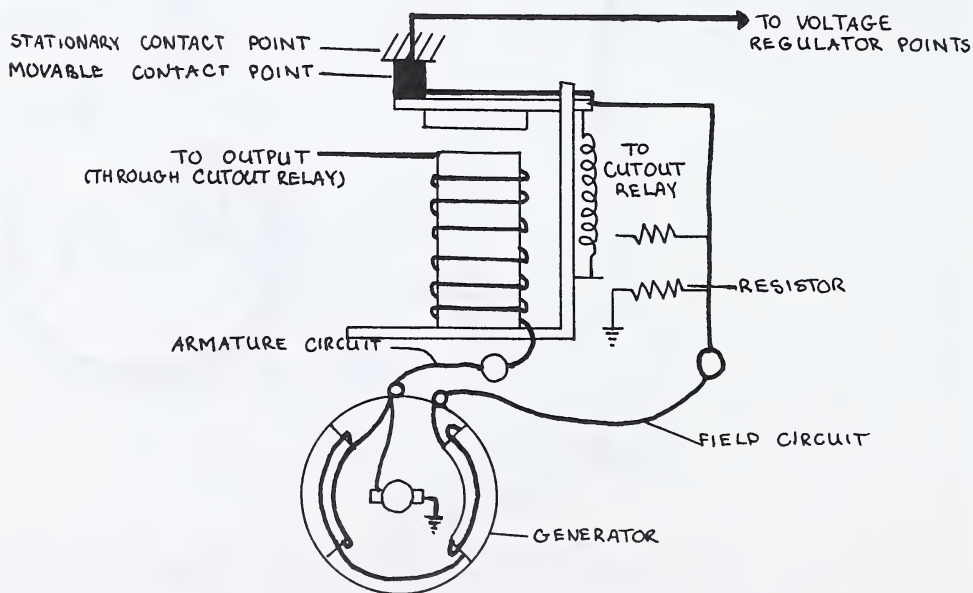
*Courtesy of John Deere Ltd.*

The cutout relay has a current coil (series windings) containing a few turns of heavy wire plus a voltage coil (shunt winding) of many turns of fine wire, both assembled on the same core. The shunt winding is connected between the generator armature and ground so that generator voltage is applied to it all of the time. The series winding is connected so that all the generator output current must pass through it. It is connected to a flat steel armature which has a pair of contact points through which the current passes to the battery and other systems. Armature spring tension holds the points open except when the unit is activated.

When the generator begins to operate, voltage builds up and forces current through a shunt winding, magnetizing the core. When the voltage reaches a value at which the relay is set, the magnetism is strong enough to overcome the spring tension and close the points. The current now flows through the series winding and out the points into the electrical system. When the generator slows down too much the magnetic field weakens and the spring pulls the points open again breaking the circuit.

**(b) Current regulator**

The current regulator automatically controls the maximum output current of the generator. When the current requirements of the electrical system increases and the battery is low, then the current regulator operates to limit the output of the generator to a safe load. This device has one series winding of heavy wire through which the entire generator output flows at all times. This winding connects to the series winding in the cutout relay. In a current regulator the points are held together when not in operation and the field circuit is completed without passing through any resistances. In this way the generator may produce maximum output unless it is controlled.



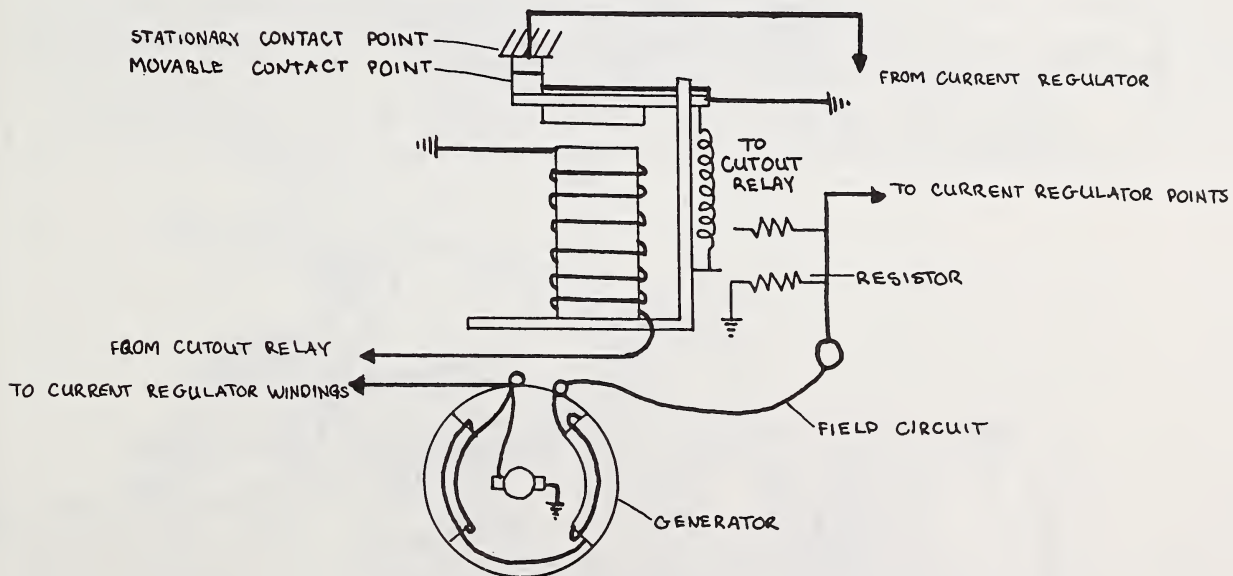
The Current Regulator

When the generator output increases to the value for which the current regulator is set, the magnetism of the current winding is sufficient to overcome the spring tension and open the circuit. The current must then flow through a resistor which holds down the current output. The points close and output increases. When points open output decreases. The points vibrate open and closed fast enough to produce a very smooth flow of current. Remember that the current regulator operates only when the condition of the battery and the load of current consuming units require maximum output by the generator. When current requirements are small the control is handled by the voltage regulator.

**Note:** Either the current regulator or the voltage regulator operates at any one time. Both regulators never operate at the same time.

### (c) Voltage Regulator

The voltage regulator limits the voltage in the charging circuits to a safe value, thereby controlling the charging rate of the generator. This is done in accordance with the needs of the battery and the other current-consuming units in operation. When the battery is low, the generator output is near its maximum. As the battery comes up to charge and other requirements are small, there is less current required and the voltage rises. The voltage regulator operates to limit this voltage thereby reducing the generator output. This protects the battery from overcharging and the electrical system from high voltage.

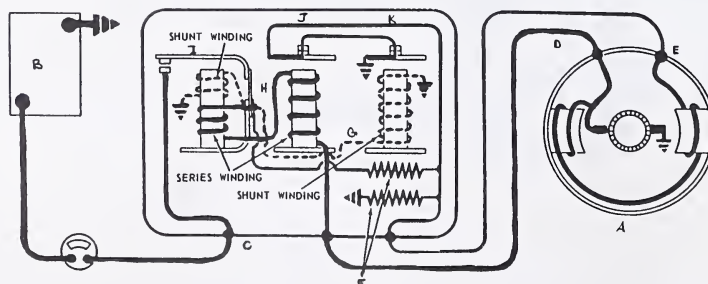


The voltage regulator unit has a shunt winding consisting of many turns of fine wire which is connected across the generator. The winding and core are assembled into a frame. A flat steel armature is attached to the frame by a flexible hinge so that it is just above the end of the core. When the voltage regulating unit is not operating the tension spring holds the armature away from the end of the core and in contact with the circuit. This allows the generator field circuit to complete the ground.

When the voltage reaches the limit set for this regulator, then the magnetic field is strong enough to overcome the spring tension and pull the breaker points apart. The instant these points are separated the field current flows only through the resistance to the ground. This will then reduce the current flow through the field coils and decreases generator voltage and output.

As previously stated, the current and voltage regulators **never** operate at the same time. When current requirements are large, the generator voltage is too low to cause the voltage regulator to operate. Therefore, the current regulator operates to limit the maximum output of the generator. When current requirements are small, the generator voltage is increased to such a value that it will activate the voltage regulator. The generator output is then reduced below the value required to operate the current regulator. Therefore all control is dependent upon the operation of the voltage regulator. This should be understandable if one remembers that current and voltage operate at inverse proportion to each other. This means that as either one increases the other decreases by the same amount and the reverse is also true.

The above operation of the opening and closing of the points in the current and voltage regulators is a continuous thing and goes on at a rate of many times per second and switching from one regulator to the other, also at a high rate per minute.



A- generator  
B- battery  
C- fuse  
D- armature lead  
E- field lead

F- resistors  
G- fine wire  
H- heavy wire  
I- cut out relay  
J- current regulator

K- simple contact voltage regulator  
L- double contact voltage regulator

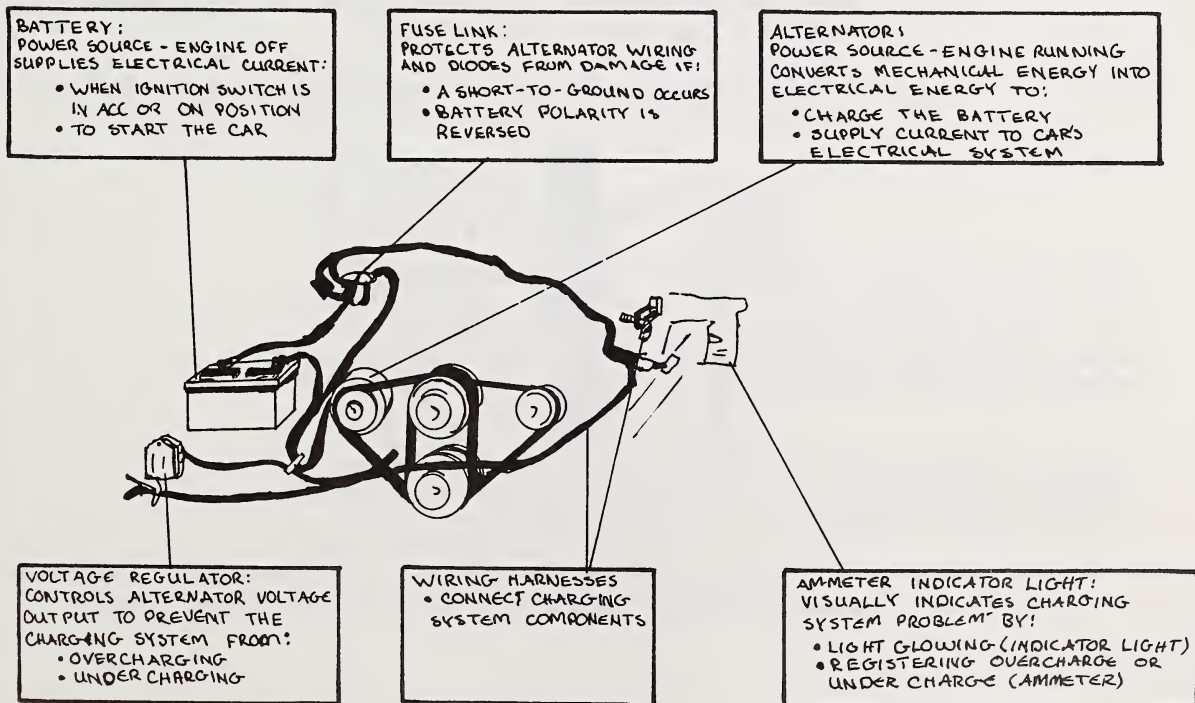
Simple Contact Voltage Regulator

**(d) Other regulator types**

Some modern vehicles make use of a partially transistorized regulator or a fully transistorized regulator. A partially transistorized regulator uses electronic components such as diodes, transistors, and capacitors to assist a regulator and give it fewer moving parts. A fully transistorized regulator has no moving parts in it and is composed entirely of solid state electronic components. This type of regulator has an excellent service life (can last a long time) and can also handle much heavier loads. Further discussion of solid state regulators occurs later in this lesson.

**AC CIRCUITS****1. Alternators**

The alternator (which can also be called an AC generator) is the major unit of the AC charging system. Alternators generally are more compact in size than generators but are able to produce a higher current at low engine speeds. This production of high current at low engine speeds is especially important in modern vehicles. In recent years more electrical accessories have been added to vehicles which cause a large current drain if used at low engine speeds. The diagram below shows the basic components of an AC alternator system and how they may be located and connected in a typical automobile.



The DC generator system was discussed earlier in this lesson. To understand how the AC alternator system overcomes various limitations of the DC generator system, you must understand how the DC system operates and what these limitations are. As mentioned earlier in this section, DC generators produce low amounts of current at low engine speeds. Generators are also relatively larger in size than alternators for similar current output. Problems with generator cooling can also occur.

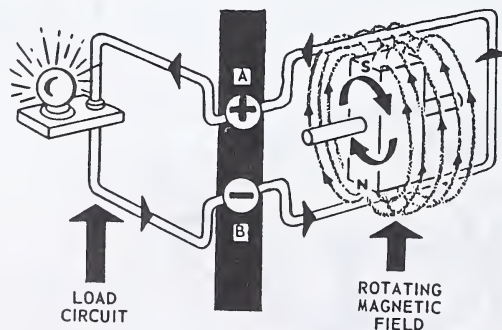
When discussing cooling problems of generators you must first realize that the DC generator actually produces alternating current. As the armature rotates through the magnetic field produced by the field coils, alternating current is induced in the armature coils, then flows through the commutator to the brushes. The commutator and brushes perform the conversion of AC to DC.

With the DC generator design, large amounts of heat are produced under high-output, low speed conditions and cooling can be a problem. Satisfactory cooling can be achieved under most conditions by changing the drive ratio to turn the generator faster at lower speeds. However, this will only hold up at low speeds. At high speeds, other problems surface (generator output becomes too great for the generator itself, pulley belts can easily break, etc.). Rather than just changing the drive ratio, something else must be done.

It has been mentioned that the automotive system cannot use alternating current directly. However, an alternating current generator can be used and the output converted to direct current. This is what an alternator does.

The alternator is composed of the same functional parts as a DC generator. However they operate differently. Whereas a generator induces current by moving a conductor through a stationary field, an alternator does the opposite. An alternator induces current by moving the field across a stationary conductor.

A basic alternator can be made by rotating a bar magnet inside a single loop of wire, as shown below. As the magnet is rotated current is induced in the wire.

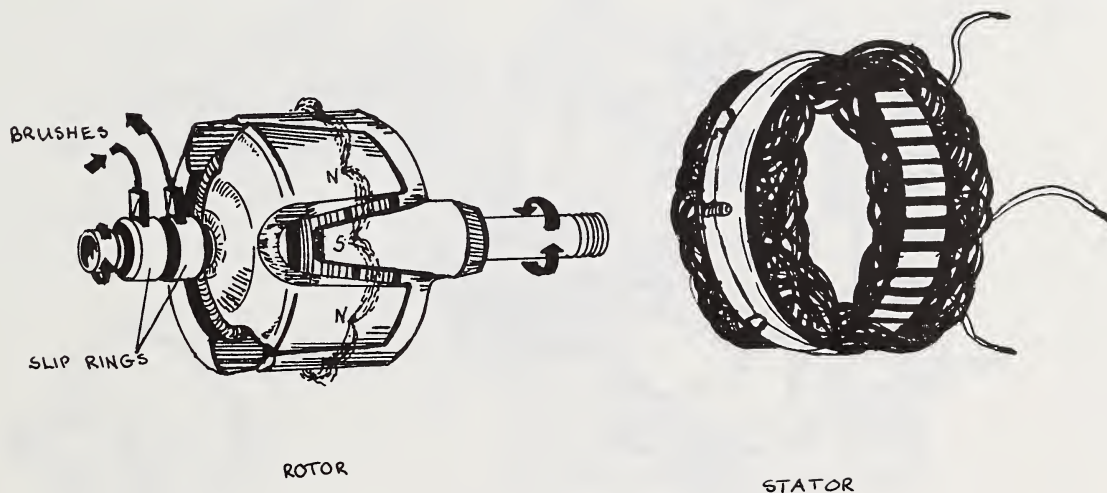


*Courtesy of John Deer Ltd.*

If the magnet rotates in the opposite direction, the current will flow in the opposite direction. The faster the magnet is turned, the more current that is induced.

Having an alternator constructed of a bar magnet rotating inside one loop of wire is not practical in automotive use since minimal voltage and current can be produced. The amount of current produced can be increased by placing the loop of wire and magnet inside an iron frame. The iron frame provides a form to which the loop of wire can be attached. It also acts as a conducting path for the magnetic lines of force and increases the number of lines of force between the North and South poles. With increased lines of force comes more induced voltage and thus a more useful alternator.

In an alternator the rotating magnet is called the **rotor**. The loop and outside frame assembly is called the **stator**. The rotor and stator which form a typical alternator are shown below.

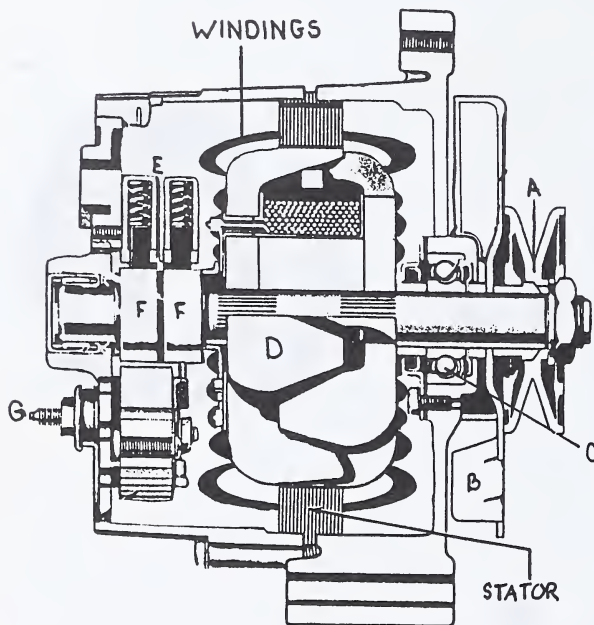


Several things should be noticed about the construction of the rotor and stator. Rather than just one wire loop the stator has many loops of wire wound in three separate coils. As well, the rotor is not constructed of a bar magnet but has pole pieces and an electromagnetic field winding. The engine drives the rotor and the field wire and the field winding is supplied current from the battery. Further discussion of alternator construction occurs later in this lesson.

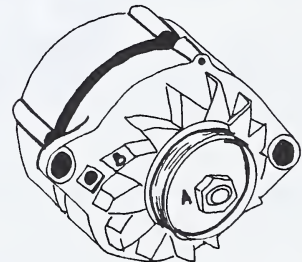
The current induced in the stator by the rotor is alternating current and this must be changed to direct current to be used by the vehicle's various accessories. The alternator uses electronic devices called diodes (which are formed into a unit called a rectifier) to change AC to DC.

It was mentioned earlier in this lesson that while an alternator is composed of the same functional parts as a DC generator, these parts operate differently. Comparing an alternator and generator, it is found that the field is the turning portion of the unit, which can be called the rotor. The part that is comparable to the armature of a DC generator is stationary and can be called the stator. The rectifier, which changes AC to DC can be compared to the commutator and brushes of a generator.

The drawings below show how the rotor, stator, and other components are joined together to make one complete alternator unit.

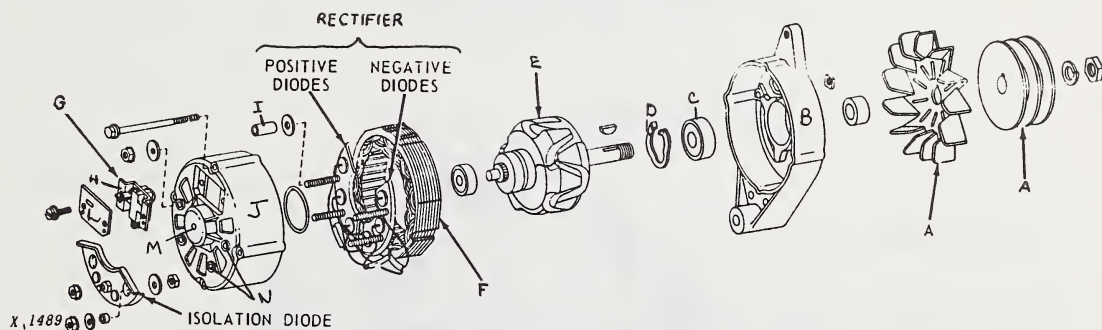


- A- Pulley
- B- Fan
- C- Bearings
- D- Rotor
- E- Brush Assembly
- F- Slip Ring
- G- Heat sink diode assembly



## 2. Alternator Construction

An alternator consists primarily of two end frame assemblies, a rotor assembly, and a stator assembly. The rotor is usually supported in the drive end frame by a ball bearing and in the slip ring end frame by a roller bearing. These bearings are usually pre-packed in lubricant and therefore do not require servicing.



*Courtesy of John Deere Ltd.*

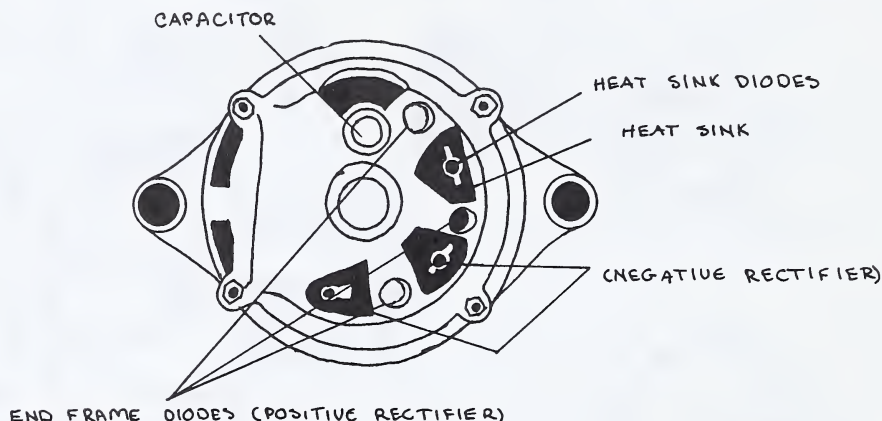
- |                     |                             |
|---------------------|-----------------------------|
| A- Pulley and Fan   | H-Brush Holder              |
| B- Front Cover      | I- Diodes (heat sink)       |
| C- Bearing          | J- Cover                    |
| D- Bearing Retainer | K- Heat Sink                |
| E- Rotor            | L- Brush Cover              |
| F- Stator           | M- Bearing Cover            |
| G- Brush            | N- Diode Mounts (end plate) |

The stator is mounted between the two end frames and consists of loops of wire wound into slots of the laminated stator frame.

The rotor contains a doughnut shaped field coil wound onto an iron spool. The coil and spool are mounted between two iron segments with several interlacing fingers which are called poles. These parts are held together by a press fit on the shaft.

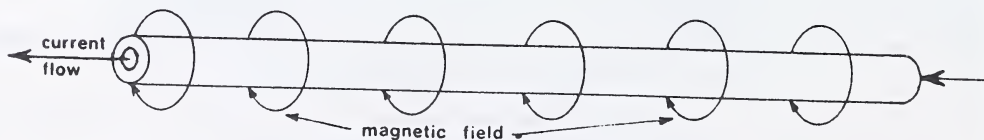
Two slip rings, upon which the brushes ride are mounted on one end of the rotor shaft and are attached to the leads from the field coils.

Each alternator has six diodes. The diodes may be considered as electronic check valves since they allow current flow in only one direction. They are located in the end frame nearest the slip rings. Three of these diodes are negative and are mounted directly to the end frame. Three positive diodes are mounted into a strip called a heat sink, which is insulated from the end frame. These diodes change the AC voltages developed in the stator windings to a DC voltage which appears at the output terminal on the alternator.

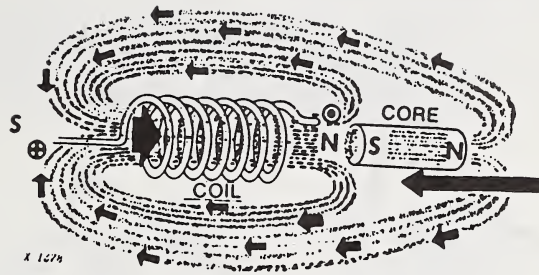


### 3. How the Alternator System Works

To understand how the alternator works, let us review some electrical fundamentals. It is a known fact that electricity and magnetism are closely related. We know that when an electric current passes through a conductor, a magnetic field is created around the wire.



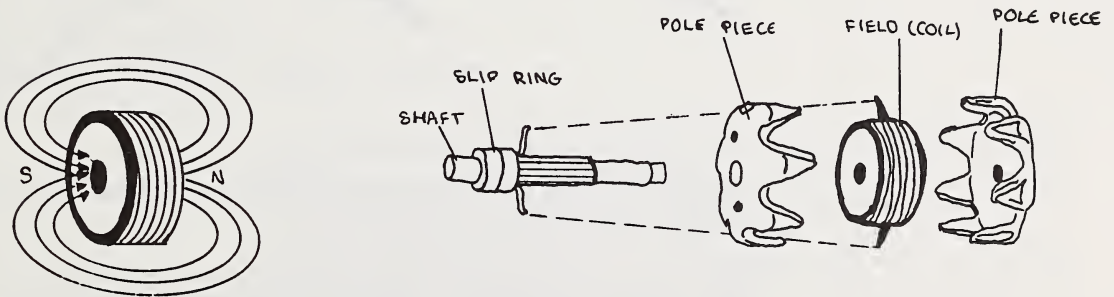
*A magnetic field around a conductor has a magnitude proportional to the amount of current flowing in the conductor.*



*Courtesy of John Deere Ltd.*

**A coil of current-carrying wire with an iron core. Field has a much higher intensity.**

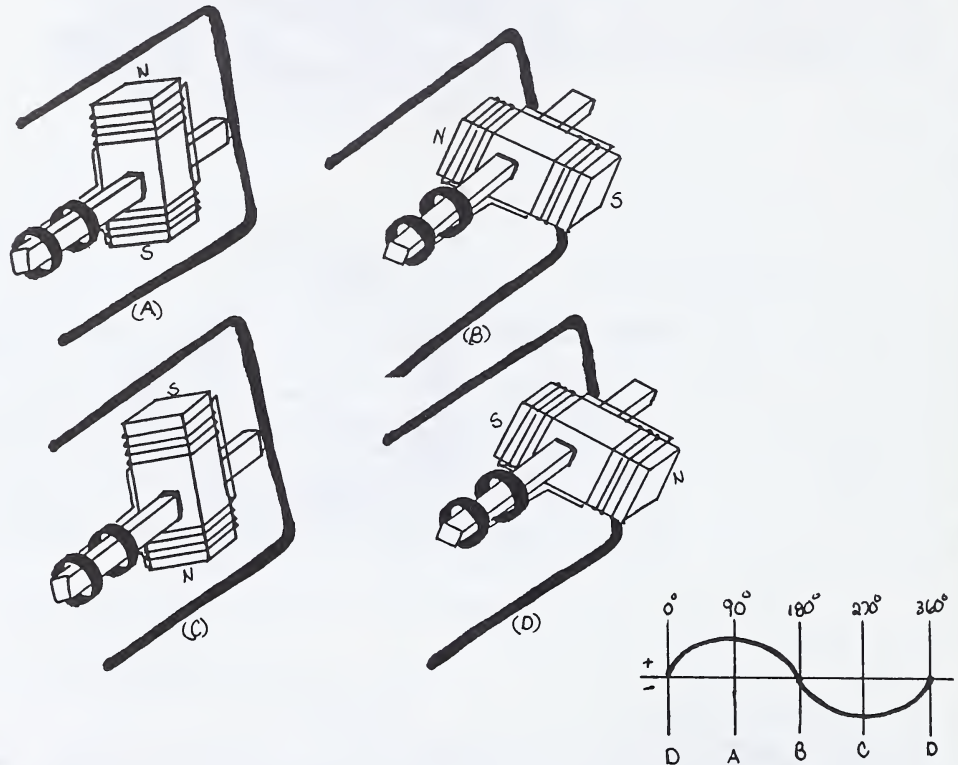
As the current in the wire increases, the strength or intensity of the magnetic field increases. However, the strength of the magnetic field around the straight conductor is too weak to be of value for most applications. So a means of obtaining a more intense magnetic field must be found. This is accomplished by winding the straight conductor in a series of loops to form a coil. We then insert an iron core in the coil and this intensifies the field still more. We now have what is called an electro-magnet with a high intensity, and very concentrated field.



This is the same principle that is used in the design of the rotor assembly of the alternator as can be seen above.

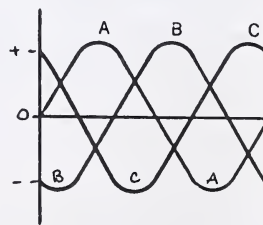
**(a) Alternator output**

Like the generator the voltage produced by an alternator has either positive or negative potential and can be illustrated by a sine wave. The sine wave produced by a simple two-pole rotor and single-coil stator in one revolution of operation is shown below.



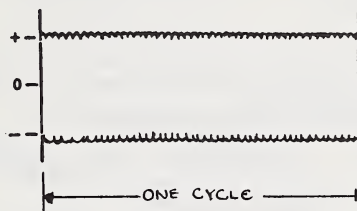
*As the rotor travels through one complete revolution of operation the positive and negative potential produces a sine wave.*

To improve an alternator's performance two extra stator windings are added. (The three sets of wires are interwoven in the stator and each set has an output current independent of the other.) Since each winding produces a single sine wave AC output (called single phase) the alternator is actually a triple sine wave AC producing device (called three phase). The sine wave output now has three separate and distinct patterns, which match the stator windings, as shown below (sine waves A, B, C).

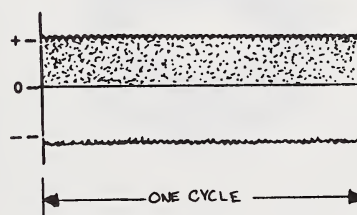


*Courtesy of Ford Motor Co.*

To improve the efficiency of AC to DC conversion (a process called rectification) additional pole pieces are added to the rotor to produce more positive and negative peaks. The sine wave produced by three stator windings and twelve pole pieces (see diagram of the stator on page 17) is nearly a solid pattern. Note that above and below the zero line of the graph the positive and negative peaks are now only a wavy line.

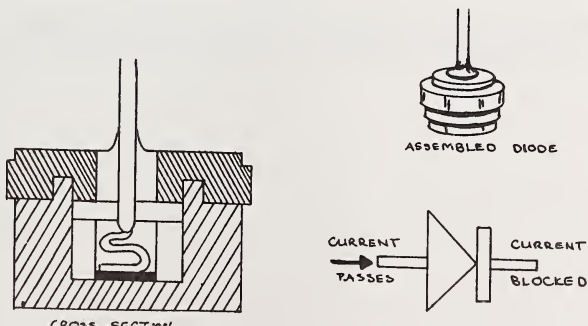


When rectified this line will produce an almost wave-free positive line as shown below.



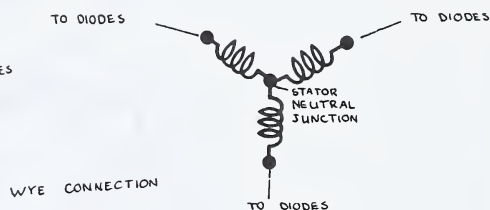
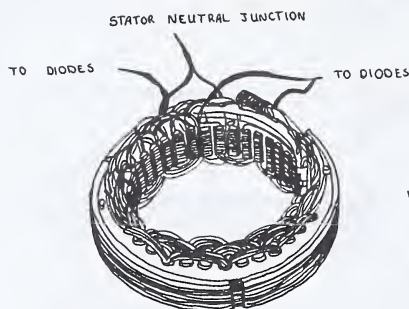
### (b) Function of the diode

It has been shown that alternating voltages are produced in the stator windings and that alternating current flows through a load when connected to the stator windings. Also it has been shown that alternating current first flows in one direction and then in the other (opposite) direction. Since the battery and all automotive electrical units operate on direct current (which flows in one direction only) it is necessary to change the AC to DC. This is the function of the diode. The chemical composition and construction of a diode is such that it will allow current flow through itself in one direction only. A cross-sectional view of a typical diode (there are several different types) is shown below. The electrical symbol for a diode is  $\rightarrow$  or  $\rightarrow$ . The illustration below indicates that current will flow in one direction only as shown. The case is sealed against moisture and connections are made through the one wire lead and also at the case of the diode.

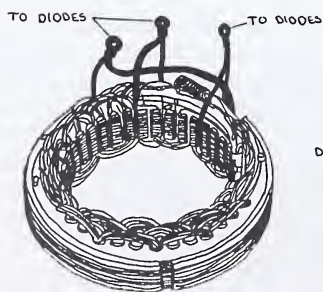


Earlier in this lesson it was mentioned that the six diodes of an alternator are mounted in the slip ring and frame of the alternator (see the drawing on page 20). Three negative diodes are mounted directly in the end frame while three positive diodes are mounted in the heat sink (which is insulated from the end frame). The above situation is used for negative ground vehicles. For positive ground vehicles the diodes are in reverse positions. The six diodes form a rectifier assembly and are responsible for converting AC received from the three stator coils to the DC required by the vehicle's electrical system.

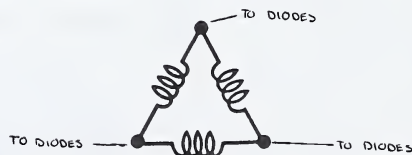
Automotive AC generators have the three sets of field windings of the stator assembly connected in one of two arrangements as shown below. In this course you shall study the Wye connection arrangement.



*Courtesy of John Deere Ltd.*

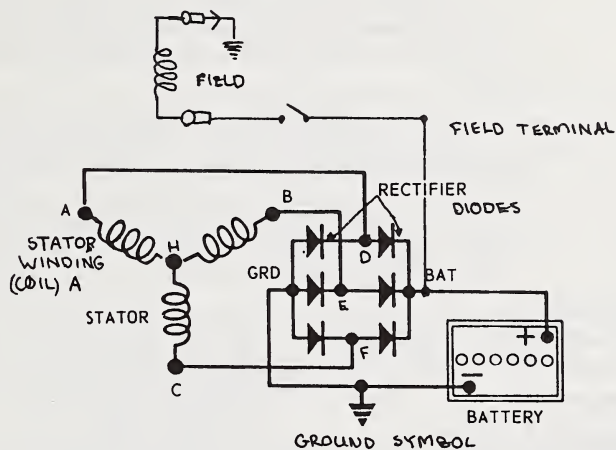


DELTA CONNECTION



*Courtesy of John Deere Ltd.*

The method by which the diodes are electrically connected to the stator is shown below. To understand how the diodes work follow the path of the current through the six diodes. Remember that current can flow only in the direction of the arrow through the diode.



*Courtesy of John Deere Ltd.*

Current will flow from points A to H through coil A where current divides to go through the other two coils to points B and C. Current goes from B to E on one path and from C to F on the other path. Current then travels through the diodes to the "BAT" connection and then via the battery (charging the battery) to the "GRD" point. From the "GRD" point current travels through a diode to D and then back to point A.

It can be likewise shown that current will flow:

- (i) From coil B through coils A and C and then back to coil B again.
- (ii) From coil C through coils A and B and then back to coil C again.

This type of circuit arrangement provides a smooth flow of direct current to the battery and other accessories in the electrical system.

#### 4. Alternator Regulators

Alternators are like generators and so must have regulation. The type of regulation is different in the two systems, however. As discussed earlier in this lesson generators required a cutout between the battery and generator plus current and voltage regulators.

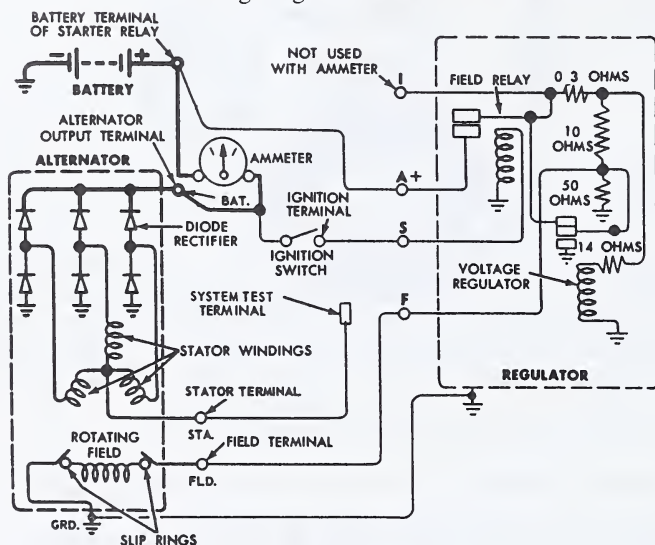
The working or one way action of the diodes prevents battery discharge back through the alternator and thus eliminates the need for a cutout relay or circuit breaker.

The alternator current output is self-limiting by the construction of the coils of the alternator so no current regulator is required.

What alternators do need is a voltage limiter (regulator). Voltage output is controlled by limiting the amount of current in the field circuit. By limiting the voltage output of the alternator, the amount of current produced is in correct proportion to both the demands of the battery (in its various states of charge) and the demands of the electrical system.

The key difference between alternator regulators and generator regulators is that alternator regulators have the cutout relay and current regulator removed.

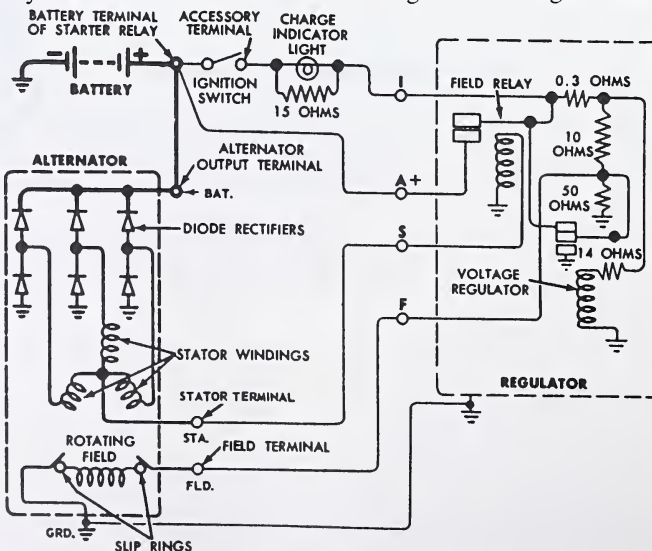
If a vehicle is equipped with an ammeter gauge rather than a dash indicator, the vehicle will usually have a single unit regulator. A single unit regulator uses only a voltage regulator and is connected in the charging circuit as shown below.



*Courtesy of Ford Motor Co.*

If, however, the vehicle uses a dash indicator light then the regulator will consist of two units, the voltage regulator and a field relay unit, as shown below. The major function of the field relay unit is the activation of the no charge indicator light on the dash of the vehicle.

*Courtesy of Ford Motor Co.*



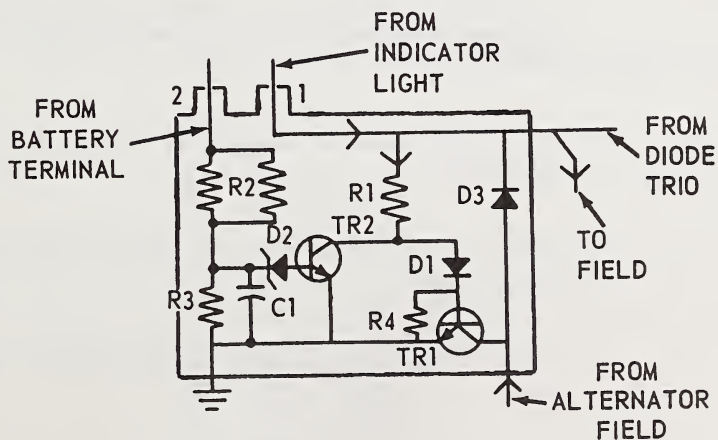
Heavy duty alternators such as those made by Leece-Neville Corporation for usage on emergency vehicles, taxis and other very high power consuming vehicles have regulators with cutout relays and current regulators mainly as back up safety features.

## 5. Solid State Regulators

In recent years, a new alternator has appeared in vehicles. It is called a "second generation" alternator and these new units take advantage of recent advances in electronic technology. In these new types of alternators the voltage regulator is an integral part of the alternator itself. These **solid state** regulators have no moving parts and are not serviceable or adjustable. They are replaced as a complete unit if defective. While the fundamental operation of the alternator remains as before (on alternators which had an external voltage regulator), overall maintenance is greatly simplified.

Solid state regulators control a vehicle's electrical system voltage by limiting the output voltage generated by the alternator. This is accomplished by controlling the amount of field current that is allowed to pass through the field windings. Basically, the electronic regulator operates as a voltage sensitive switch.

An electronic regulator contains a variety of electrical components connected in certain types of circuits, depending on the manufacturer. Usually several transistors, diodes, resistors, and capacitors are included. A larger transistor is placed in series with the alternator field winding and a control circuit which senses the system voltage. This control unit turns the transistor on and off many times per second to keep the field current and alternator output voltage at proper levels. In some cases an electronic device called an integrated circuit is used instead of transistors. The integrated circuit takes up less space in an alternator. An integrated circuit contains transistors, resistors, diodes, capacitors, etc. combined in a micro-circuit. A schematic drawing of a typical electronic voltage regulator is shown below. As you can see electronic voltage regulators can be very complex.



*Courtesy of John Deer Ltd.*

There are many variations of alternator and generator regulators. These will be discussed in detail in more advanced courses.

Answer the following Self-Correcting exercises. Check your answers with those at the end of the lesson.

### SELF-CORRECTING EXERCISE 1

Answer each of the following questions either "True" or "False" by placing the appropriate answer in the space provided.

- \_\_\_\_\_ 1. A voltage regulator is sensitive to current fluctuations.
- \_\_\_\_\_ 2. The diode assembly is the alternator component which rectifies alternating current.
- \_\_\_\_\_ 3. The conditions need for electromagnetic induction are a conductor, a magnetic field, and relative motion between the conductor and field.
- \_\_\_\_\_ 4. During normal engine operation at high speeds the battery supplies most of the current needed to operate a vehicle's accessories while the alternator provides very little current.
- \_\_\_\_\_ 5. A shunt generator has the field circuit placed in series with the external circuit.
- \_\_\_\_\_ 6. In an AC charging system an alternator or a generator can be used to produce current.
- \_\_\_\_\_ 7. In a generator most of the current produced is sent to the field coils to maintain the magnetic field strength while a small percentage is sent to the external circuit.
- \_\_\_\_\_ 8. The wiring harness in a vehicle is used to connect charging system components.
- \_\_\_\_\_ 9. Cooling can be a major problem for DC generators under high load, low speed conditions.
- \_\_\_\_\_ 10. An alternator produces current by moving a conductor through a stationary field.

**SELF-CORRECTING EXERCISE 2**

Answer each of the following by choosing the **best** answer.

- \_\_\_\_\_ 1. Which of the following is **not** a function of a regulator in a generator-based charging system?
- (a) to open and close the charging circuit between the generator and battery
  - (b) to control the generator's output current
  - (c) to prevent the battery from being overcharged
  - (d) to control the amount of current flowing out of the battery when initially starting an engine
- \_\_\_\_\_ 2. A generator changes the alternating current it produces to direct current by the use of
- (a) a stator and rotor.
  - (b) the commutator and brushes.
  - (c) diodes in the rectifier circuit.
  - (d) the armature and commutator.
- \_\_\_\_\_ 3. An alternator changes AC to DC by the use of
- (a) the rotor and stator.
  - (b) commutator and brushes.
  - (c) diodes.
  - (d) transistors.
- \_\_\_\_\_ 4. In an alternator the magnetic field is produced by the
- (a) armature.
  - (b) rotor.
  - (c) stator.
  - (d) external circuit.
- \_\_\_\_\_ 5. Which of the following units is **not** contained in a generator regulator?
- (a) cutout relay
  - (b) current regulator
  - (c) voltage regulator
  - (d) field relay unit

- \_\_\_\_\_ 6. The generator regulator unit which prevents the battery from discharging to ground when the engine is stopped is called
- (a) the cutout relay.
  - (b) the current regulator.
  - (c) the voltage regulator.
  - (d) none of these, it is the ignition switch which prevents discharging.
- \_\_\_\_\_ 7. The only wearing parts in the alternator are the bearings plus the
- (a) rotor.
  - (b) diodes and rotor.
  - (c) brushes and slip rings.
  - (d) commutator and brushes
- \_\_\_\_\_ 8. The DC regulator controls generator output by inserting a resistance into which circuit?
- (a) armature
  - (b) stator
  - (c) field
  - (d) rotor
- \_\_\_\_\_ 9. A regulator on an AC charging system has one major job to do. What is it?
- (a) limit the voltage to a safe value
  - (b) limit the current to a safe value
  - (c) open and close the charging circuit
  - (d) control alternator speed
- \_\_\_\_\_ 10. The field frame of a generator is usually constructed of which metal?
- (a) iron
  - (b) steel
  - (c) copper
  - (d) aluminum

**SELF-CORRECTING EXERCISE 3**

Fill in the blanks with the most appropriate word or words.

1. A block of conducting substance (such as carbon) used as the contact point with the commutator is called \_\_\_\_\_.
2. A generator converts \_\_\_\_\_ energy to electrical energy.
3. In a generator the part which is moved through a magnetic field to produce current is called \_\_\_\_\_.
4. The outside frame assembly of an alternator is part of the \_\_\_\_\_ unit.
5. The current induced in the stator of an alternator by the rotor is \_\_\_\_\_ current.
6. The \_\_\_\_\_ and \_\_\_\_\_ of a generator can be compared to the rectifier unit of an alternator.
7. An alternator has \_\_\_\_\_ diodes of which \_\_\_\_\_ are positive and mounted in the end frame and \_\_\_\_\_ are negative and are mounted in a metal strip called a \_\_\_\_\_.
8. Most modern alternators are three-phase AC producing devices which contain \_\_\_\_\_ stator windings.

Complete the following exercises and send them in for correction.

### EXERCISE 1

1. Although both alternators and generators produce current, they differ in the way they produce the current. How do they differ?

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2. What is the function of the fan attached to the drive pulley of a generator?

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3. Why does an alternator contain twelve pole pieces rather than just having a simple two-pole rotor?

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4. What does the process of rectification involve?

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5. What is the major difference between alternator regulators and generator regulators?

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6. How do "second generation" regulators differ from conventional regulators?

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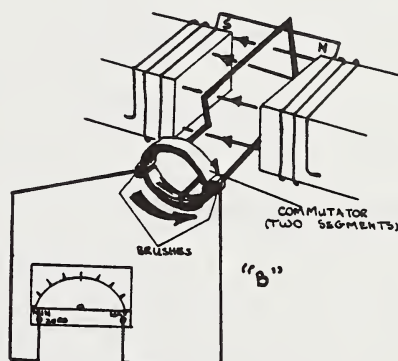
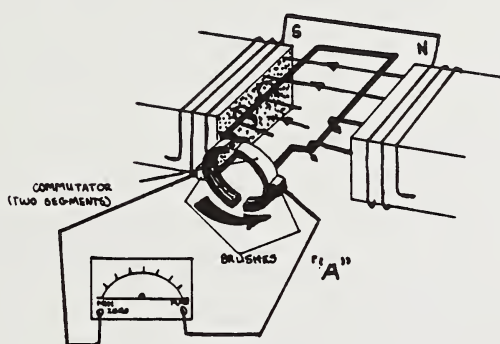
7. What is the major advantage of using "second generation" regulators?

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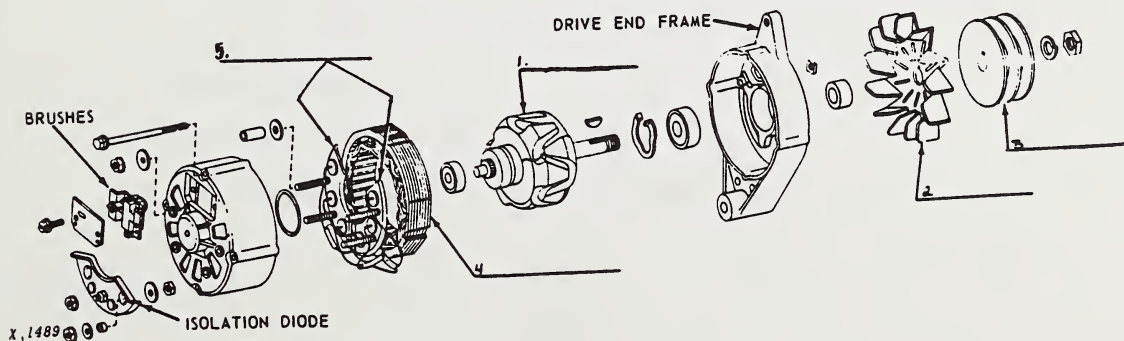
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## EXERCISE 2

1. In figures "A" and "B" show the voltage reading on the voltmeters by drawing in the position of the pointer.



2. Identify the following alternator parts by filling in the following five blanks.



*Courtesy of John Deere Ltd.*

**ANSWERS TO SELF-CORRECTING EXERCISES****Self-Correcting Exercise 1**

- |                        |                             |
|------------------------|-----------------------------|
| 1. T (page 12)         | 6. F (page 2)               |
| 2. T (pages 18 and 21) | 7. F (page 4)               |
| 3. T (page 3)          | 8. T (see diagram, page 13) |
| 4. F (pages 1-2)       | 9. T (page 14)              |
| 5. F (page 5)          | 10. F (page 14)             |

**Self-Correcting Exercise 2**

- |                       |                |
|-----------------------|----------------|
| 1. d (pages 8-12)     | 6. a (page 9)  |
| 2. b (pages 2 and 14) | 7. c (page 18) |
| 3. c (page 15)        | 8. c (page 12) |
| 4. b (pages 15-16)    | 9. a (page 24) |
| 5. d (page 8)         | 10. b (page 8) |

**Self-Correcting Exercise 3**

- |   |                                  |
|---|----------------------------------|
| 1. brushes (page 4)                           |                                  |
| 2. rotating mechanical (or magnetic) (page 5) |                                  |
| 3. armature (page 5)                          | 6. commutator, brushes (page 16) |
| 4. stator (pages 16-17)                       | 7. 6, 3, 3, heat sink (page 18)  |
| 5. alternating (pages 15-16)                  | 8. 3 (pages 20-21)               |

# LESSON RECORD FORM

1746 Mechanics 12  
Module 2

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Time Spent on Lesson

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(If label is missing  
or incorrect)

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- (1) All pages are numbered and in order, and no paper clips or staples are used.
- (2) All exercises are completed. If not, explain why.
- (3) Your work has been re-read to ensure accuracy in spelling and lesson details.
- (4) The Lesson Record Form is filled out and the correct lesson label is attached.
- (5) This mailing sheet is placed on the lesson.

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Do not enclose letters with lessons.

Send all letters in a separate envelope.

#### **3. POSTAGE RATES**

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Take your lesson to the Post Office and have it weighed. Attach sufficient postage and a green first-class sticker to the front of the envelope, and seal the envelope. Correspondence lessons will travel faster if first-class postage is used.

Try to mail each lesson as soon as it has been completed.

When you register for correspondence courses, you are expected to send lessons for correction regularly. Avoid sending more than two or three lessons in one subject at the same time.

## THE STARTING SYSTEM

Introduction  
 Electric Motors  
 Basic Starting Circuit  
 Starting Motor Construction  
 Starting Motor Operation  
 Starter Drives  
 Starting Motor Switches

### INTRODUCTION

Earlier this century the automobile engine was turned over or cranked by hand using a mechanical crank in order to get the engine started. This was an efficient method at that time of the vehicle's development. Today we use an electric motor to do the cranking job for us.

Any electric motor is virtually an electric generator in reverse. Where a generator converts mechanical power to electrical power, the electric motor converts electrical power back to mechanical power. All the rules, laws and descriptions mentioned so far relating to electricity and magnetism will still hold true when discussing a vehicle's starting system.

The cranking (or starting) system is designed to change electrical energy from the battery to mechanical energy used by the starter. The system must turn the engine over at a certain speed so the engine can begin to run when the cylinders begin to fire.

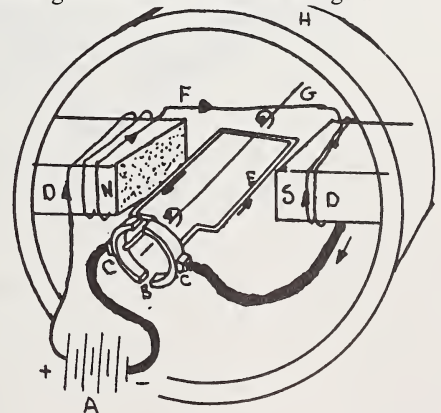
### ELECTRIC MOTORS

In lesson 8 it was mentioned that generators are available as series wound and shunt wound types. Since electric motors are so similar to generators it should come as no surprise that there are two types of motors, one being a series wound motor while the other is a shunt wound motor.

#### 1. Series Wound Motor

In a series wound motor the field coil windings and the armature windings are in series with each other.

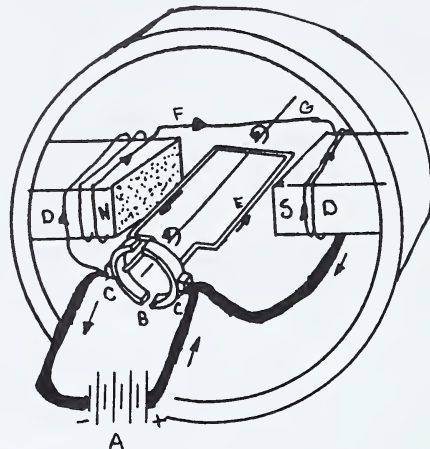
A - Battery      E - Armature  
 B - Commutator   F - Field Coil  
 C - Brushes      G - Axis of rotation  
 D - Poles Shoes   H - Case



## 2. Shunt Wound Motor

In a shunt wound motor the field coil windings are in parallel with the armature windings.

- A - Battery
- B - Commutator
- C - Brushes
- D - Pole Shoes
- E - Armature
- F - Field Coil
- G - Axis of rotation
- H - Case

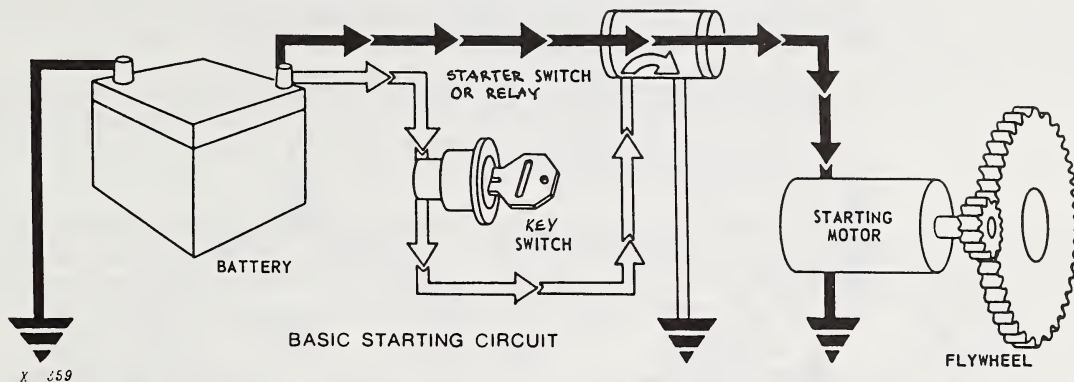


In the automobile both types of motors are used. The fan motor in an automobile heater, for example, is shunt wound. This type of winding gives a constant maximum speed. This is because the field strength has a certain value for a given voltage. The weaker the field, the slower the fan runs. This action usually comes under the direct control of switches on a vehicle's dash.

In contrast to the above situation, the starting motor is series wound. This is because the series type of winding provides maximum armature torque (or turning effort) at zero speed. This is just what is required to start the engine moving.

## BASIC STARTING CIRCUIT

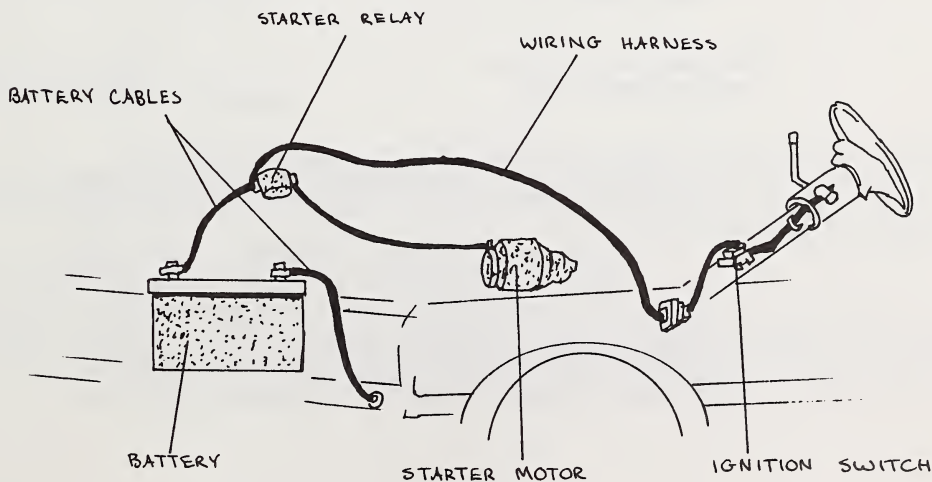
A basic starting circuit has four parts as shown below.



*Courtesy of John Deere Ltd.*

1. The battery supplies electrical energy for the circuit.
2. The key switch activates (turns on) the circuit.
3. The starter switch connects the battery to the starter motor. (In some cases it engages the motor drive with the engine flywheel.)
4. The starting motor turns the flywheel so the engine may be started.

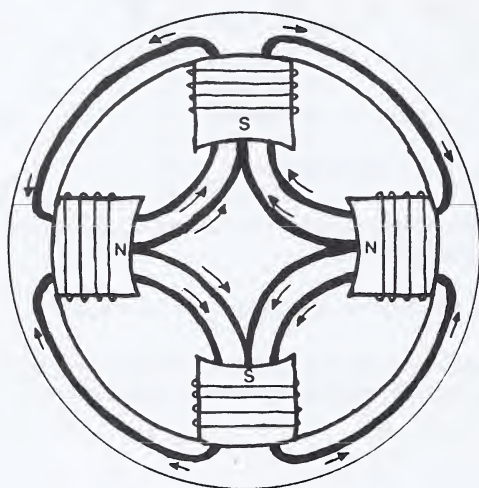
The drawing below illustrates where the four parts are located in a typical vehicle. Locations of individual parts may vary depending on vehicle manufacturer.



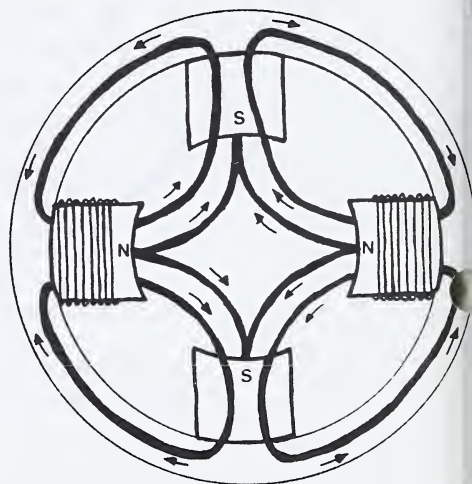
When the starter switch is first closed, the battery supplies a heavy amount of current to the starter motor (about 300 A in a 12 V system). This heavy current produces extremely strong magnetic fields in both the field poles and the armature coils of the starter motor. The armature will turn over. After only a few seconds the armature is up to its normal cranking speed and the amperage has dropped (to about 150 A in a 12 V system).

If a fully charged battery registering 12 V is considered, the battery voltage will drop to 9 V when the starter is in operation because the battery is unable to change its chemical energy fast enough to maintain 12 V. However, the 9 V is adequate enough to force 150 A through the starter to drive it at a normal speed.

One slight difference in the automobile cranking motor over other motors is that automotive cranking motors always have four poles in order to provide sufficiently strong magnetic fields. These are required in order to produce adequate power for turning the engine over. On some cars that have smaller engines only two of the four poles have windings on them.



Standard type on Larger cars especially V-8's.

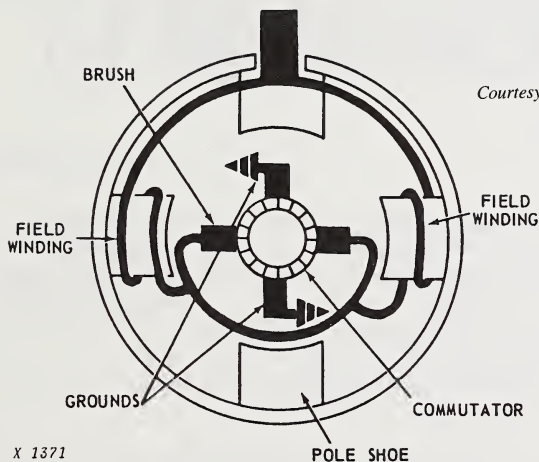


Type found on smaller cars usually 4 cylinder types.

As can be seen in the above drawings the magnetic circuit remains the same in both cases, the fields are not as strong when only two poles are wound.

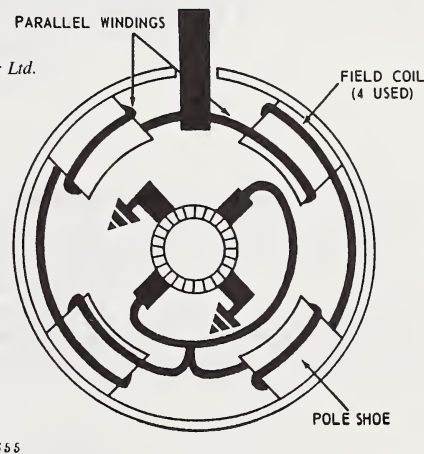
In the four pole motor there are two pairs of field coils instead of one pair as is shown on pages 2 and 3. Therefore, four brushes are required. It is interesting to note that with 9 V across the armature and a 150 A current flowing through the starter, the number of watts absorbed by the starter is 1350 W (or 1.35 kw). Of this amount about 0.35 kw is wasted through heat plus electrical and mechanical loss. This leaves about one kilowatt of power available to turn over the engine.

As we know when electricity flows, heat is generated. Therefore, all electrical apparatus must be designed with conductors of such a size that the temperature rise is not sufficient to char the insulation or melt it. All wires, whether inside electrical units or connecting these units in the circuits, must be of sufficient size. The size or capacity of an ignition coil, regulator, starter, or generator, are all designed with this temperature factor in mind. If it were not for the temperature problem, a much smaller electrical unit could be made to produce the same results.



Two Field Starter Motor

- A - Pole Shoes
- B - Ground
- C - Commutator
- D - Brushes



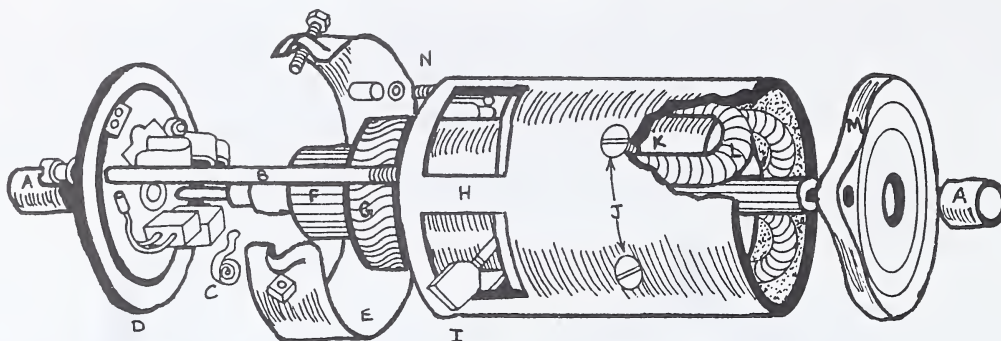
Four Field Starter Motor

- E - Armature Shaft
- F - Field Coil
- G - Equalizer Wire
- H - Outer Case

## STARTING MOTOR CONSTRUCTION

The starting motor has a round tubular housing called the field frame (or main case). At one end is the commutator end frame which carries the brushes and at the other end the appropriate drive unit is attached. The commutator end frame may be made of cast iron or steel. "Thru bolts" travel from the commutator end frame to the drive housing so that when bolted together the starter becomes a three piece unit.

The field coils are wound snugly around the pole shoes and this entire unit is attached to the field frame by large screws. The armature shaft is supported by bearings. These bearings are usually in the form of bushings but sometimes a ball bearing is used at the drive end. Bushings may be bronze or they may be a porous copper material impregnated with oil.

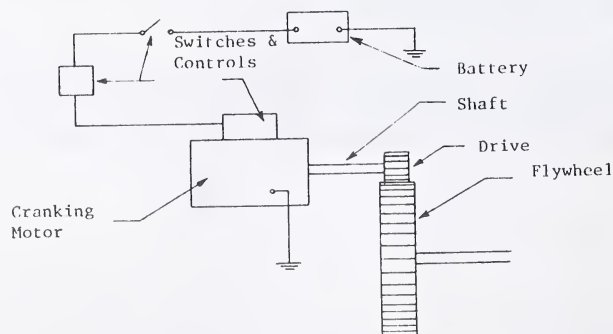


- |                          |                 |                     |
|--------------------------|-----------------|---------------------|
| A - Bearings             | F - Commutator  | K - Pole Shoes      |
| B - Thru Bolt            | G - Armature    | L - Field Coils     |
| C - Brush Spring         | H - Field Frame | M - Drive End Plate |
| D - Commutator End Frame | I - Brush       | N - Power Terminal  |
| E - Dust Cover           | J - Pole Screws |                     |

The armature core is made of numerous laminations of soft iron about 0.8 mm thick which are insulated from each other by very thin sheets of paper or special varnish. If a solid iron core were used rather than a laminated core, the solid iron core would generate small voltages in various parts of itself. This would result in small currents flowing in various directions throughout the armature core. These currents represent wasted energy. This energy would also heat up the armature sufficiently so that it would be unable to function at its proper efficiency. Using insulated laminations in the core almost completely eliminates this problem. The voltage and current generated in any individual lamination is almost negligible.

## STARTING MOTOR OPERATION

As mentioned earlier in this lesson the starting circuit includes a storage battery, a starter switch, a small but powerful electric starter motor, and the necessary conductors to join these into a circuit.



As the flywheel turns the crankshaft also turns and therefore the entire engine turns over.

When the starter switch is closed (this may be built into the key switch), current flows from the battery through the starter rotating the armature. On one end of the starter armature shaft is a pinion gear which meshes with a larger ring gear on the rim of the flywheel. The cranking motor drives the ring gear which in turn rotates the engine.

The normal ratio between a ring gear and pinion gear is about 15 to 1 which means that once the engine starts, it drives the starter armature 15 times as fast as the engine is rotating. Even though the just-started engine only rotates at a moderate speed of about 1 000 r/min. This speed can wreck an armature because of centrifugal force. So it is necessary to provide some means of near instant disengagement of the starting motor from the ring gear when the engine starts.

## STARTER DRIVES

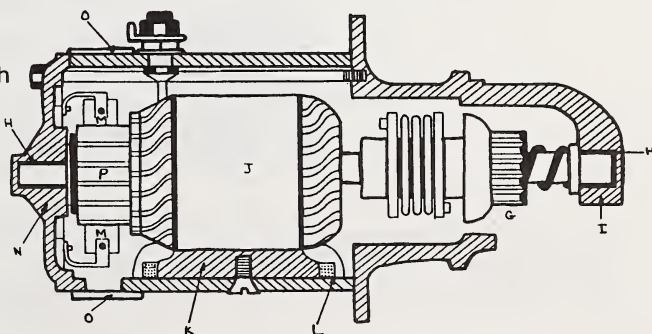
It is necessary to mesh (or engage) the pinion gear of the starting motor with the flywheel in order to turn the engine over and get it started. As well, when the engine has started, it is necessary for the pinion gear to be demeshed (or disengaged) from the flywheel.

While there are many different starter drives in use, they can all be classified under two basic types according to the way in which the pinion gear engages the flywheel. These two types are the self-engaging or inertia drive and the mechanically-engaged or clutch drive.

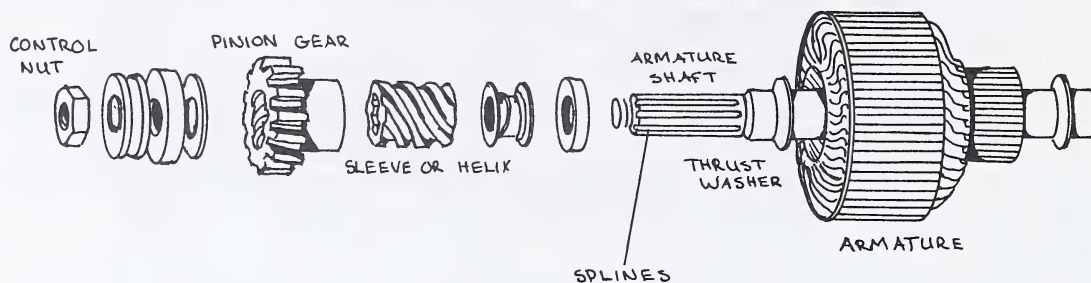
### 1. Inertia Drive

Inertia drives have a pinion gear that is weighted on one side to aid in engaging and disengaging with the flywheel. The most common type of inertia drive used in modern vehicles is of the Bendix type. The diagram below shows a cut-away view of a starter with a Bendix drive.

- A - Solenoid
- B - Plunger Linkage
- C - Shift Lever
- D - Shift Ring
- E - Shift Spring
- F - Overrunning Clutch
- G - Pinion Gear
- H - Bushing Bearing
- I - Housing
- J - Armature
- K - Pole Shoe
- L - Field Coil
- M - Brushes
- N - Commutator Plate
- O - Inspection Cover
- P - Commutator



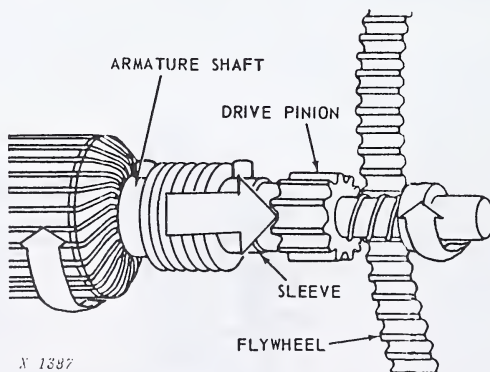
A drawing showing basic parts of a typical bendix drive is shown below.



As can be seen in the above drawing, the threads on the sleeve are very coarse. The pinion gear is mounted on the sleeve. The inside of the sleeve is also splined to correspond with splines on the armature shaft. When the armature rotates the pinion moves up the thread because of the counterweight which gives more inertia to the pinion. This inertia is what causes the pinion to screw up (travel up) the threads and into mesh with the flywheel gear. The following description and diagrams give an indepth study of the operation of the bendix drive.

With the ignition switch "off", the bendix drive is retracted and does not mesh the pinion and flywheel gears.

With the ignition switch in the "start" position, the starting switch is closed and battery voltage is applied to the starting motor so that the armature shaft will turn and accelerate rapidly.

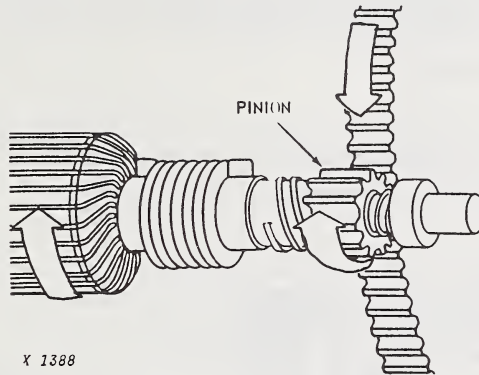


X 1387

Courtesy of John Deere Ltd.

Bendix drive engaging flywheel as engine is cranked

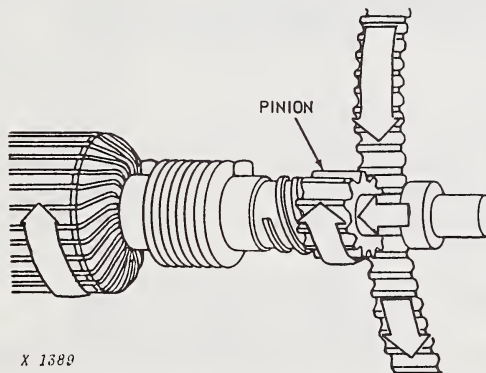
Centrifugal force will act on the counterweight causing the pinion gear to move forward on the revolving screw sleeve until the pinion gear engages the flywheel gear.



*Courtesy of John Deer Ltd.*

Bendix Drive Pinion Fully Meshed

When the pinion becomes totally meshed with the flywheel the forward motion of the pinion stops. (The pinion gear reaches its stop point.) This locks the pinion to the rotating armature shaft. The heavy cushion drive spring absorbs the sudden shock of pinion engagement. The shaft then starts to turn the flywheel.



*Courtesy of John Deer Ltd.*

Bendix Drive Pinion Spinning Out of Mesh After Engine Starts

When the engine starts, the flywheel turns faster than the armature shaft, which causes the pinion to reverse its travel on the threaded sleeve. It will spin backwards, free of the flywheel gear. The engine is thus prevented from turning the starter motor at excessive speeds.

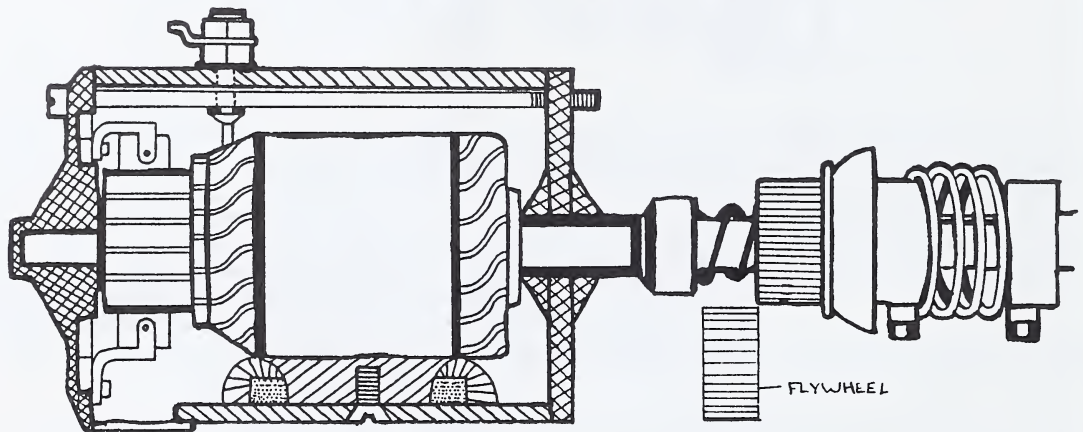
To prevent the pinion from accidentally becoming meshed again with the flywheel, such as may occur when travelling over rough roads or up steep hills, a small coiled antidrift main spring is used to hold the pinion away from the flywheel.

**(a) Outboard bendix**

The diagram on page 7 shows a cut-away view of a starter with an outboard bendix drive. In this type of starter the entire bendix drive unit is enclosed by the starter housing. Bushings are used to support both ends of the starter drive. The pinion gear spins outwards to engage the flywheel.

**(b) Inboard bendix**

The inboard bendix drive has the drive unit totally exposed and it overhangs out of the cranking motor as shown below.



Operation of the inboard bendix drive unit is the same as the outboard bendix drive unit except that the outboard bendix has the pinion gear assembly move outwards from the starter motor unit to engage the flywheel while the inboard bendix starter has the pinion move inwards (closer to the starter housing) when being engaged.

**(c) Precautions**

Several precautions must be followed when using a starter unit with a bendix drive.

- (i) The key switch should be immediately released once the engine has started. If the key switch is not released the starter armature will still rotate causing the centrifugal force on the counterweight to force the pinion gear in so it is not totally unmeshed. This may damage the armature.
- (ii) During repeated attempts to start an engine, allow the engine to come to rest before attempting to use the starter again to turn over the engine. Damage to the starter's drive housing or bendix spring could result if the pinion gear attempts to re-engage the flywheel while the engine turns backwards. (The engine has a tendency to turn backwards immediately after it stops in order to release compression in the cylinder.)

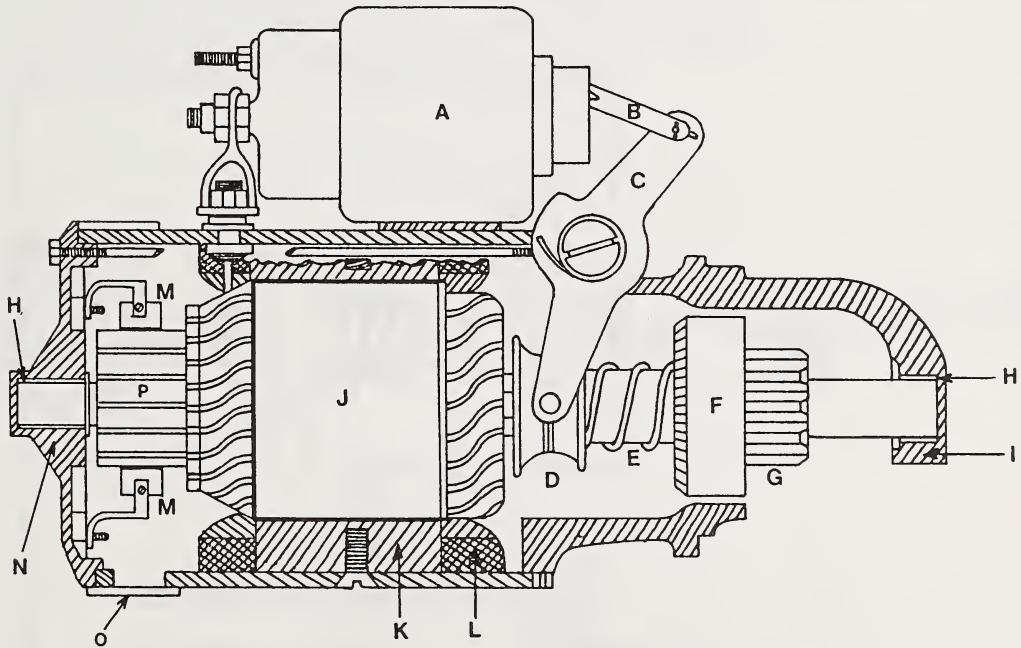
- (iii) Engine ignition timing should be checked and any corrections made in order to prevent backfiring. If the engine backfires during starting, great stress is placed on the starter since the pinion is meshed with the flywheel. The starter motor uses the pinion to turn the engine over in one direction while backfiring causes the engine to reverse direction jamming the drive pinion in the opposite direction which can damage the bendix spring.

## 2. Clutch Drive

Clutch drives (also known as mechanically engaged drives) use linkages which are manually operated or use an electric solenoid to activate the shift linkage. In either of these cases the result is that the pinion gear is engaged in the ring gear.

The overrunning clutch drive uses a shift lever to move the drive pinion along the armature shaft, into or out of mesh, with the flywheel ring gear.

Cranking Motor with Overrunning Clutch Drive

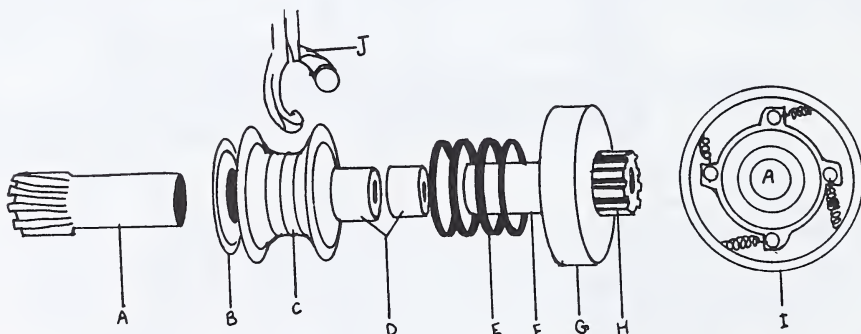


A - Solenoid  
B - Plunger Linkage  
C - Shift Lever  
D - Shift Ring  
E - Shift Spring  
F - Overrunning Clutch  
G - Pinion Gear  
H - Bushing Bearing

I - Housing  
J - Armature  
K - Pole Shoe  
L - Field Coil  
M - Brushes  
N - Commutator Plate  
O - Inspection Cover  
P - Commutator

The built-in shift lever moves a collar (or shift ring) towards the flywheel, compressing the shift spring which pushes on the overrunning clutch to which the pinion is attached. The overrunning clutch is splined to the armature shaft and slides freely on it. The purpose of the shift spring is to allow it to compress in the event that the teeth on the pinion butt against the teeth of the ring gear. In this case, the compression of the spring permits the starter switch to be closed even with the teeth butting instead of meshing. Once the armature starts to turn and the pinion turns to where the teeth are lined up then it will immediately engage.

There are four cylindrical rollers resting between the driving member and the driven member of the unit. These rollers are located in suitable slots. The outer surfaces of the slots are slightly sloped or tapered and each roller is forced toward the tapered end of its slot by a small coil spring. When the driving member is rotated in a clock-wise direction the rollers firmly wedge themselves between the driving and driven members. This then causes the driven member to be rotated positively by the driving member of the unit. When the motor starts it drives the pinion in a clockwise direction at a speed much greater than that of the driving member. The driven member moves away from the driving member. This moves the rollers clockwise out of their jammed position and allows the driven member to run free with respect to the driving member. In this manner the high speed of the pinion can not be transmitted back to the armature. As soon as the driver disengages the starter switch the pinion will return to its unmeshed position.



One Type of Overrunning Clutch Drive

A - Armature Shaft  
B - Lock Ring  
C - Collar  
D - Bushings  
E - Clutch Spring

F - Sleeve  
G - Drive Shell  
H - Pinion Gear  
I - Detail of Inside of Drive Shell  
J - Shift Lever

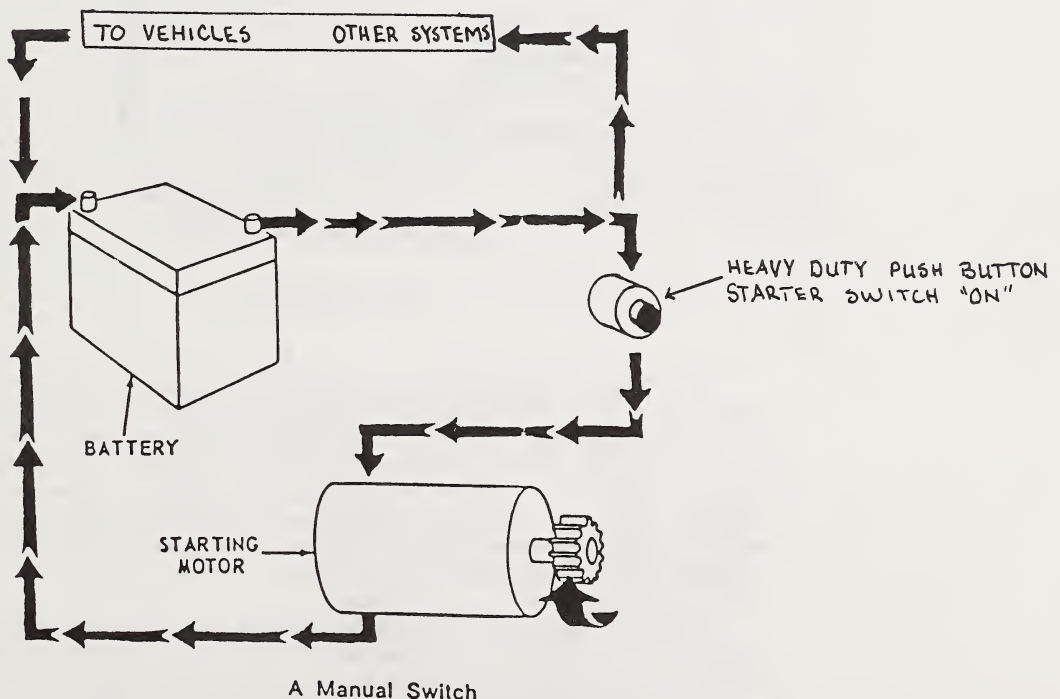
## STARTING MOTOR SWITCHES

A starting motor is used to start a vehicle's engine but the starter must be quickly turned off once the engine does start. This is the purpose of the starter motor switch. There are a variety of switches in use today but in this course you will study two types - the manual switch and the magnetic switch.

### 1. Manual Switches

A manual switch is a simple mechanically operated device which is hand controlled to open or close a circuit. In the home a light switch is a manual type switch. In vehicles manual switches are used to control many of a vehicle's accessories such as the heater motor and power windows.

In some vehicles in order to start the engine two mechanical switches must be used. The key switch is turned "on" to provide power to the vehicle's circuits and then a second manual switch is used to activate the starter itself. (Older cars and trucks had the starter switch mounted on the floorboards and pressed by the foot to turn the starter.

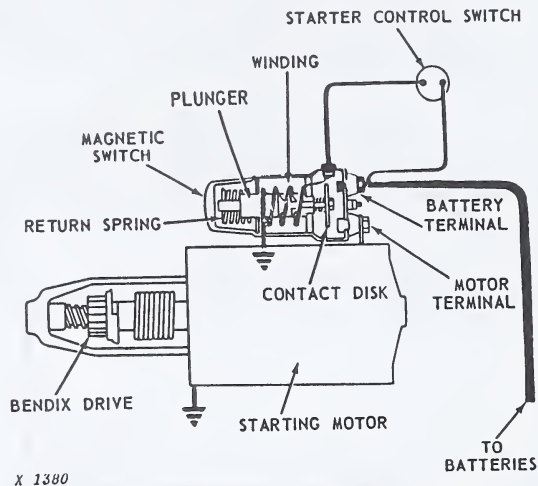


*Courtesy of John Deer Ltd.*

## 2. Magnetic Switches

Magnetic switches use the principle of electromagnetism to operate. As you learned earlier in this course a current carrying coil creates a magnetic field. The field may be strengthened by placing an iron core in the coil. If the core is free to move and is placed at one end of the coil it will assume the polarity of the coil and therefore be pulled into the coil.

A starter using a magnetic starter switch operates in the following way.



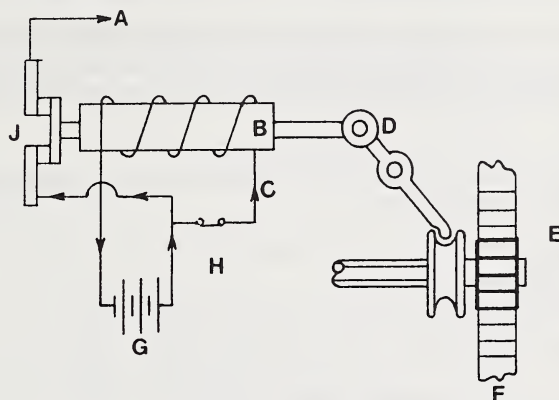
A Typical Magnetic Switch Circuit

*Courtesy of John Deere Ltd.*

When the key switch is in the "start" position, the circuit to the winding is closed, current flows, and a magnetic field is created in the plunger core. The core moves, overcoming spring tension, and causes the contact plate to complete the circuit across the terminal contacts. This in turn causes the main starting motor circuit to be complete and the starter turns over causing the engine to start. When the engine starts and the key switch is put to the "on" position, the magnetic field collapses and the return spring causes the contact plate to disconnect the terminals. This causes the starting motor circuit to open and the starting motor will stop turning.

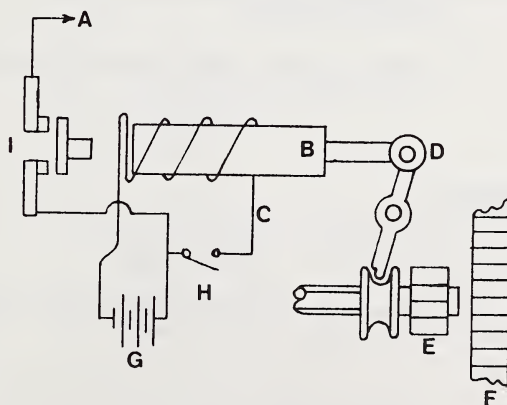
One type of magnetic switch which is commonly used is the solenoid switch. The solenoid switch also uses electromagnetism as a basis for its operation. The solenoid switch, however, is more complicated in that it also provides a mechanical method of moving the pinion gear into engaging and disengaging the flywheel.

The solenoid switch has its iron core connected to a mechanical linkage which moves the pinion gear. Study the diagrams below plus the drawing of the overrunning clutch on page 11 of this lesson.



Engaged

- |                                  |                           |
|----------------------------------|---------------------------|
| A - To Starter Motor             | F - Flywheel Ring Gear    |
| B - Solenoid Plunger (iron core) | G - Battery               |
| C - Solenoid Coil                | H - Dash or Key Switch    |
| D - Linkage                      | I - Starter Switch Open   |
| E - Pinion Drive Gear            | J - Starter Switch Closed |



Disengaged

The key point to remember about solenoid switches is that they provide a mechanical means of moving the starter motor pinion so that it can engage and disengage from the flywheel ring gear.

You may have observed the relationship that occurs between starter drives and starter switches. Inertia-type drives use straight magnetic switches while clutch-type drives always use solenoid switches and a mechanical shifting mechanism.

Answer the following Self-Correcting Exercises. Check your answers with those listed at the end of this lesson.

### SELF-CORRECTING EXERCISE 1

Answer each of the following statements either "True" or "False."

- \_\_\_\_\_ 1. An electric motor is virtually an electric generator in reverse.
- \_\_\_\_\_ 2. A shunt wound motor produces constant maximum speed.
- \_\_\_\_\_ 3. The normal ratio between a ring gear and pinion gear is 15 to 1.
- \_\_\_\_\_ 4. The inertia drive is also known as the mechanical drive.
- \_\_\_\_\_ 5. A starter motor is series wound.
- \_\_\_\_\_ 6. The armature core is made of numerous laminations of hard iron.
- \_\_\_\_\_ 7. A starting motor is designed to operate for short periods of time but with large current flow.
- \_\_\_\_\_ 8. Bushing bearings used to support the armature shaft are made of a porous bronze material.

### SELF-CORRECTING EXERCISE 2

Fill in the blanks with the best word or words.

- 1. The starting circuit converts electrical energy from the battery into \_\_\_\_\_ energy to turn over the engine.
- 2. The name of the unit that connects the starting motor to the flywheel ring gear during operation is the \_\_\_\_\_.
- 3. The type of starting motor that has the drive portion extending free from the case of the starter and the pinion moving inwards towards the starter housing when being engaged is known as the \_\_\_\_\_ bendix.

4. An overrunning clutch mechanism allows the clutch drive pinion to safely \_\_\_\_\_ the starter motor armature when the engine starts.
5. There is a direct relationship between starter drives and starter switches in that inertia drives use \_\_\_\_\_ switches while clutch drives use \_\_\_\_\_ switches.

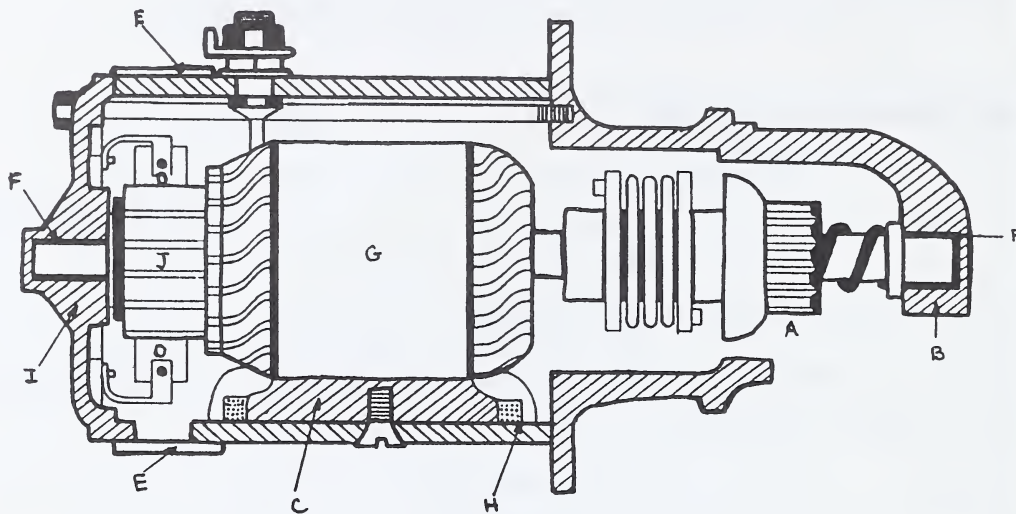
### SELF-CORRECTING EXERCISE 3

Choose the answer which best completes the following sentences.

- \_\_\_\_\_ 1. The operation of both the magnetic and solenoid type starter switches depend on
- (a) friction and current flow.
  - (b) a core tightly wrapped around a coil of wire.
  - (c) two bar magnets applying a force to each other.
  - (d) the movement of a magnetized core into and out of an electromagnetic coil.
- \_\_\_\_\_ 2. The ring gear is mounted on the
- (a) armature shaft.
  - (b) flywheel.
  - (c) pinion drive.
  - (d) bendix drive only.
- \_\_\_\_\_ 3. The sudden shock of pinion engagement is absorbed in the bendix type starter by the
- (a) drive spring.
  - (b) antidrift spring.
  - (c) pinion gear stop.
  - (d) shift ring.
- \_\_\_\_\_ 4. The type of starter switch that uses a solenoid plunger and contact plate but no mechanical linkage assembly is the
- (a) manual switch.
  - (b) solenoid switch.
  - (c) magnetic switch.
  - (d) overrunning switch.
- \_\_\_\_\_ 5. In a typical starting circuit the battery is connected to the starter motor by using the
- (a) key switch.
  - (b) starter switch.
  - (c) flywheel.
  - (d) pinion gear.

**SELF-CORRECTING EXERCISE 4**

Name the parts.



- |          |          |
|----------|----------|
| A. _____ | E. _____ |
| B. _____ | F. _____ |
| C. _____ | G. _____ |
| D. _____ | H. _____ |
| J. _____ | I. _____ |

Please complete the following exercises and send them in for checking.

**EXERCISE 1****Short Answer**

1. What is one difference in starter motors found on vehicles with large engines compared to those found on small engined vehicles?

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2. What is the difference between an inboard bendix starter and an outboard bendix starter?

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3. What are the two basic functions of the starter drive?

(a) \_\_\_\_\_

(b) \_\_\_\_\_

4. What is the main difference between a magnetic starter switch and a solenoid starter switch?

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5. Why is engine ignition timing so critical when trying to turn over an engine that has a bendix starter?

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6. Why is the clutch shift spring so important in a starter that has an overrunning clutch drive?

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**ANSWERS TO SELF-CORRECTING EXERCISES****Self-Correcting Exercise 1**

- |                   |                   |
|-------------------|-------------------|
| 1. True (page 1)  | 5. True (page 2)  |
| 2. True (page 2)  | 6. False (page 6) |
| 3. True (page 7)  | 7. True (page 4)  |
| 4. False (page 7) | 8. False (page 5) |

**Self-Correcting Exercise 2**

- |                                     |                                 |
|-------------------------------------|---------------------------------|
| 1. mechanical (page 1)              | 4. overrun (page 12)            |
| 2. pinion (or pinion gear) (page 7) | 5. magnetic, solenoid (page 16) |
| 3. inboard (page 10)                |                                 |

**Self-Correcting Exercise 3**

- |                    |                |
|--------------------|----------------|
| 1. d (pages 14-15) | 4. c (page 14) |
| 2. b (page 7)      | 5. b (page 3)  |
| 3. a (page 9)      |                |

**Self-Correcting Exercise 4**

- |                     |                          |
|---------------------|--------------------------|
| A. pinion gear      | F. bushing bearing       |
| B. housing          | G. armature              |
| C. pole shoe        | H. field coil            |
| D. brushes          | I. commutator plate      |
| E. inspection cover | (see diagram on page 11) |



## LESSON RECORD FORM

1746 Mechanics 12  
Module 2

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## THE IGNITION SYSTEM

- Introduction
- Ignition Circuit Operation
- Ignition System Components
- Electronic Ignition
- Computer Controlled Ignition Timing
- Summary

### INTRODUCTION

The purpose of a vehicle's ignition system is to take the low voltage supplied by the battery and create a high enough voltage at the spark plugs so that a combustible mixture in the cylinders may be ignited. The principal units of an ignition system are the battery, ignition switch, induction coil, distributor (points and condenser), spark plugs, and the wire to connect these units. The shaft of the distributor is the only mechanical connection to the internal workings of the engine. This shaft is rotated by the drive gear of the camshaft.

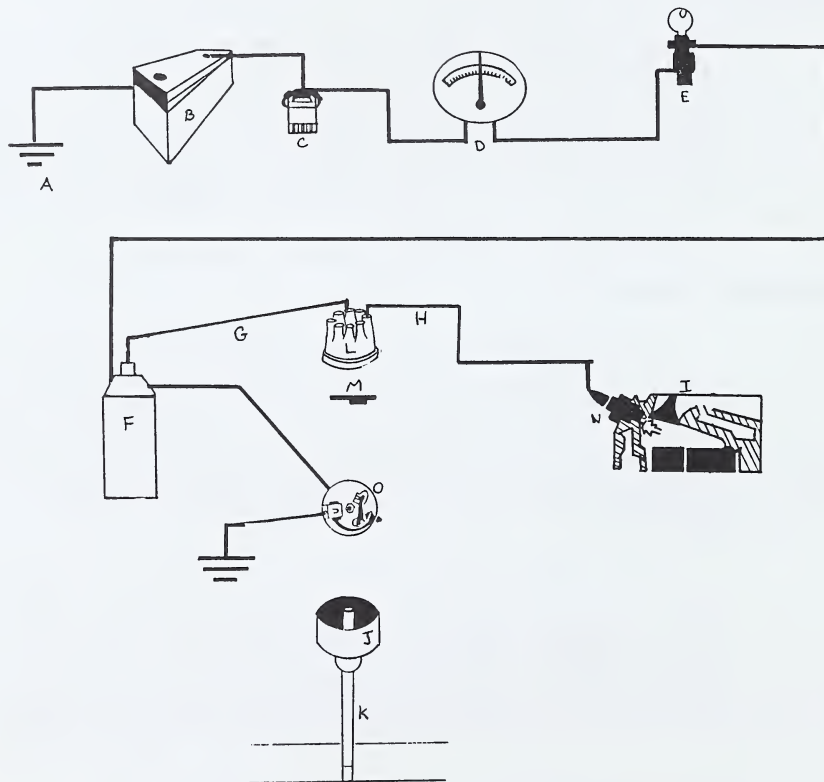
### IGNITION CIRCUIT OPERATION

A vehicle's ignition circuit is actually a combination of two separate circuits, called the primary (or low tension) circuit and the secondary (or high tension) circuit. The primary circuit carries the low voltage (usually 12 V) from the battery. The primary circuit includes the battery, ignition switch, coil primary winding, distributor contact points, and condenser. The secondary circuit of this same 12 V system can produce as much as 30 000 V. The secondary circuit includes the coil secondary winding, distributor rotor, distributor cap, and spark plugs.

As was mentioned earlier in this course, we can think of voltage as an electrical pressure which forces current through the circuit against the resistance of the circuit. Thousands of volts are required in the secondary circuit to force the current through the very high resistance of the air gap between the spark plug electrodes. The low voltage that we have in the primary circuit is changed to high voltage in the secondary circuit by means of an induction coil. This coil is more commonly known as an ignition coil in the automobile.

A - Ground Line  
 B- Battery  
 C - Connection at Starter  
 D - Ammeter  
 E - Ignition Switch  
 F - Coil  
 G - Lead to Center of Distributor  
 H - Spark Plug Leads  
 I - Engine Head  
 J - Distributor  
 K - Cam Shaft

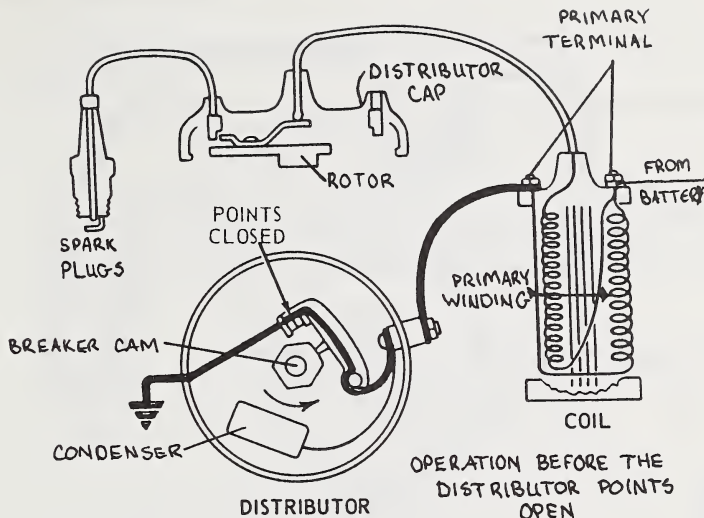
L- DISTRIBUTOR CAP  
 M- ROTOR  
 N- SPARK PLUG  
 O- ADVANCE PLATE (with Points AND Condenser)



Line Drawing of An Ignition System

### 1. Operation With Contact Points Closed

With the contact points closed and the ignition switch turned on, current will flow from the battery into the primary windings of the coil as shown on the next page. From the primary winding, current travels through the closed contact points in the distributor to ground.



*Courtesy of John Deere Ltd.*

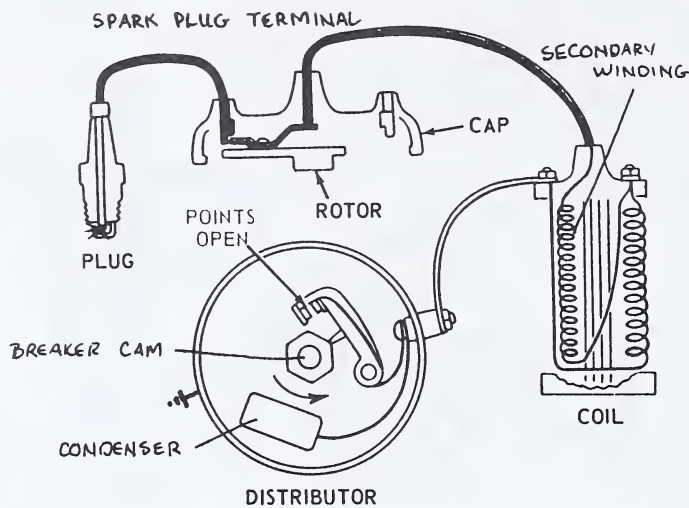
### Operation Before the Distributor Points Open

Whenever a current flows, a magnetic field surrounds the current. The magnetic field is concentrated by the many turns of wire in the primary coil. This magnetic field is further intensified by the presence of an iron core. The magnetic field which is created by the current flow in the primary circuit, completely permeates the secondary windings and represents magnetic energy which is in storage. The stored magnetic energy which completely surrounds both the high and low-tension windings remains in storage as long as the current continues to flow through the low-tension circuit.

### 2. Operation With Contact Points Open

The instant the contact points open, current stops flowing and the magnetic field immediately collapses around the two windings. This collapsing field induces (produces) high voltage and therefore a current in the two windings.

One way to explain this phenomenon is to note that the magnetic field produced by the primary windings consists of magnetic lines of force. We know that if we move a wire through a set of magnetic force lines we produce current in the wire. In this case the wire is stationary but when the field collapses the lines of force retract to the iron core, and are cut as they pass the coil windings.



*Courtesy of John Deere Ltd.*

### Operation After the Distributor Points Open

This sudden increase (or surge) of induced voltage in the primary winding is absorbed by the condenser. The surge of voltage in the secondary winding (which is much larger) travels to the distributor cap. In the distributor cap a rotor contacts a spark plug terminal and directs the voltage surge to the spark plug via a spark plug cable. At the spark plug, the current travels through the centre electrode until it reaches the spark plug gap. The current arcs across the gap creating a spark and then flows to the engine block. The circuit is complete when current has flowed from the grounded engine block back through the battery to the secondary windings of the coil.

The complete cycle of current entering the primary winding, points opening, current being induced in the secondary, and current travelling through the distributor to the spark plug occurs very rapidly (ranging from 100 to 300 times per second depending on engine speed).

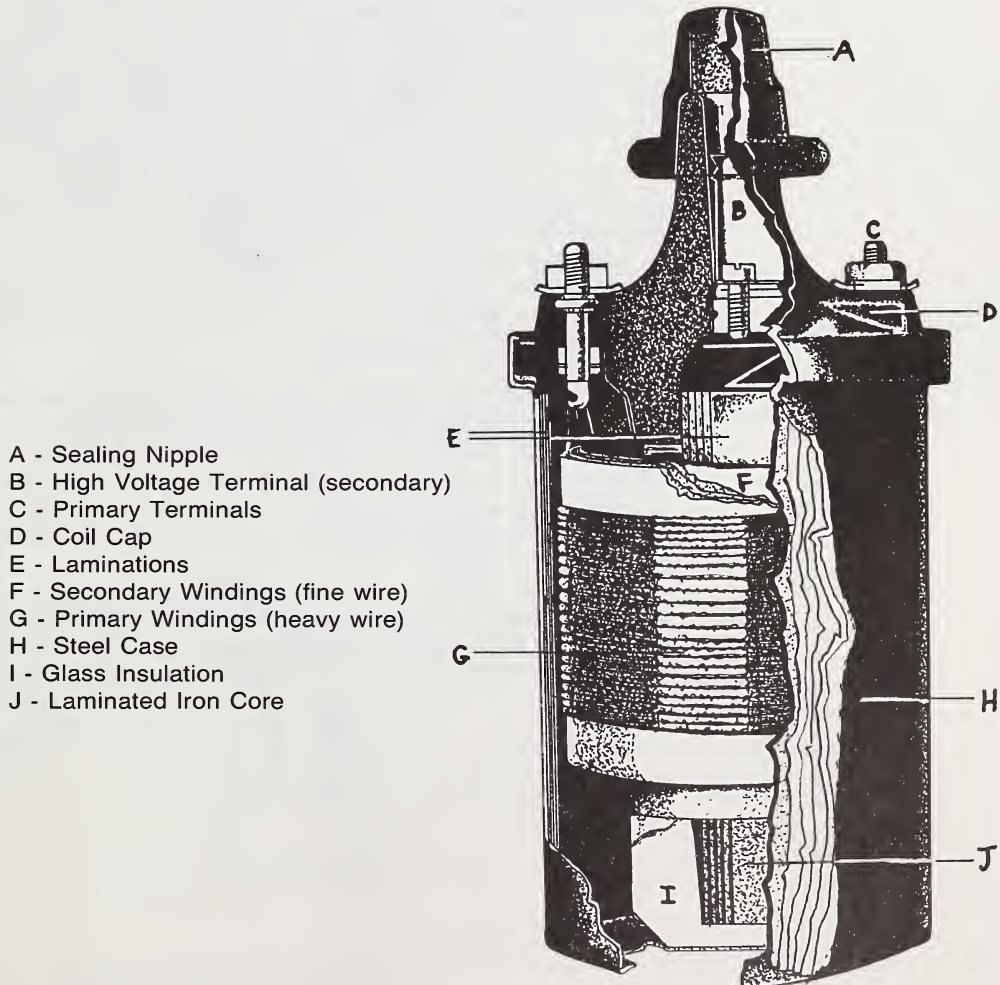
## IGNITION SYSTEM COMPONENTS

### 1. The Ignition Coil

An ignition coil contains two coils of wire, one being part of the primary circuit while the other is part of the secondary circuit.

Twelve volts flow through the primary circuit when the points are closed. However, when the points open and the magnetic field collapses, a much higher voltage is induced in the primary winding of the coil. The voltage that is induced in the primary winding may range from 100 to 300 V depending on the number of turns in the coil.

A typical coil consists of 240 turns of coarse wire and 21 000 turns of very fine wire. This gives a turn ratio of  $\frac{21\ 000}{240} = \frac{87.5}{1}$  or 87.5 to 1.



Tests show that the maximum voltage that the secondary winding is capable of producing is approximately equal to the ratio of the turns multiplied by the induced voltage in the primary circuit. Therefore, if the induced voltage in the primary circuit is 200 V, then the voltage in the secondary circuit will be  $(200 \text{ V} \times 87.5 = 17\,500 \text{ V})$ .

The actual voltage required for a spark to jump the gap in a spark plug ranges from 5 000 to 20 000 V, depending on many factors. The first main factor is the breadth of the gap. As the gap gets larger the voltage required increases proportionally. The second main factor is that the amount of voltage required also increases considerably with increased compression pressure in the cylinder chamber. The compression can range from 1000 kPa with the throttle open, down to a pressure of about 250 kPa when the engine is idling. Therefore, if the car is running at an idle with a moderate plug gap the voltage required could be as low as 5 000 V.

It was mentioned earlier in this lesson that once a spark has jumped the gap, the circuit has been completed because current has flowed. Therefore, regardless of throttle opening or plug gap the voltage induced in the windings will increase until it is sufficient to jump the gap or it has reached its limit for that size of coil. The induced voltage will never increase beyond that which is required jump the gap. For example, if you have a coil that can produce 25 000 V, on a car that at idle requires only 5 000 V for a spark, then 5 000 V is all that will be produced while the car is idling. On open throttle, this same car may require a maximum of 21 000 V, so when the car is operating at full throttle the coil will operate at the 21 000 V level and not exceed this amount.

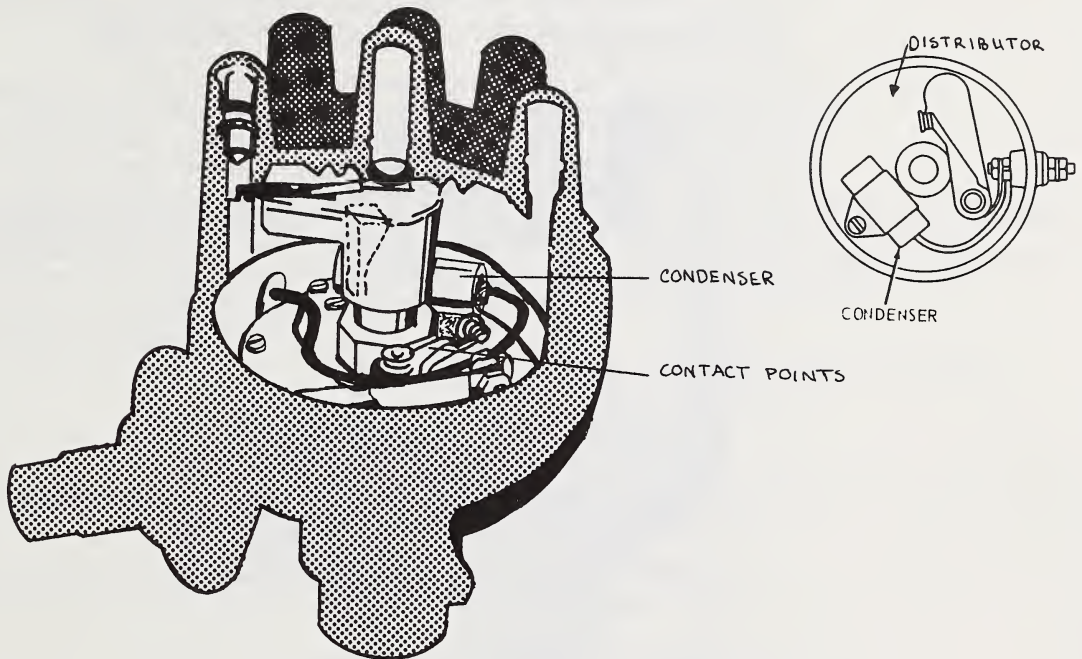
There is always an excess voltage capacity built into the coils so that the spark can still be delivered after the ignition system wears down or gets into a condition other than that which is theoretically perfect. For example, a slightly loose or dirty connection anywhere in the low-tension circuit might reduce the current flowing through this circuit enough to reduce the maximum voltage of the secondary winding by as much as a few thousand volts. However, the coil is so constructed as to still operate as long as there is not too many of these problems.

Note that the iron core used in a coil is laminated because a solid iron core would generate stray currents within itself caused by the rapid build up and collapse of the magnetic field. This could result in an excess of heating in the coil and as mentioned earlier too much heat in electrical units is another unwanted quantity. This heating effect is largely eliminated by making the core out of many laminations. This is also true of the metal shield which surrounds the coil just inside the protective case.

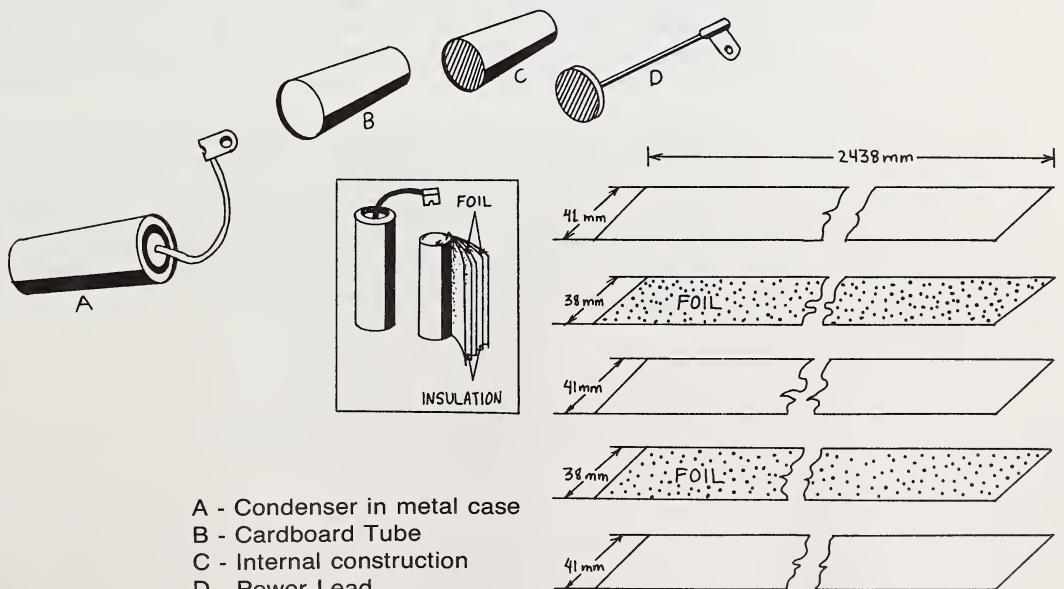
A factor to remember is that the secondary circuit runs only out from the secondary windings through the center terminal of the coil to the center terminal of the distributor cap and then out through an outside terminal of the cap to its respective spark plug. All of the rest of the wiring in the ignition system belongs to the primary circuit.

## 2. Condenser

The condenser is connected across the contact points as shown below.



A typical condenser consists of two strips of tin foil that are 25 to 38 mm in width and 2.4 m in length. These strips are sandwiched between three strips of tissue-thin translucent paper which is about 3 mm wider than the foil. The paper is usually impregnated with a special insulating compound. The condenser is encased in a metal housing which is usually about 16 mm in diameter.



- A - Condenser in metal case
- B - Cardboard Tube
- C - Internal construction
- D - Power Lead

The two foil strips are lined up with opposite edges of the paper. This ensures that there is no direct contact between the two strips. The strips are then rolled into a cardboard tube. This tube is dipped in solder to give a larger surface contact at each end of the tube for each sheet of foil. The condenser is so constructed that the capacity (capacitance) of it will match the capacity of the coil that it is to be used with.

A condenser has two major functions. The condenser absorbs current surges produced by the induced voltage from the primary winding. The condenser also makes a cleaner break of current flowing past the contact points. Because it makes this clean break in the primary circuit the primary current collapses more rapidly and this induces a higher secondary voltage in the secondary windings. When the points are snapped open the electricity tries to arc or jump across the gap to continue flowing. The condenser greatly reduces this arcing but does not eliminate it entirely. Arcing is what burns the points in the distributor. If excessive arcing across the points is noticed then most likely there are condenser problems (if there is not a loose connection).

### 3. The Ignition Distributor

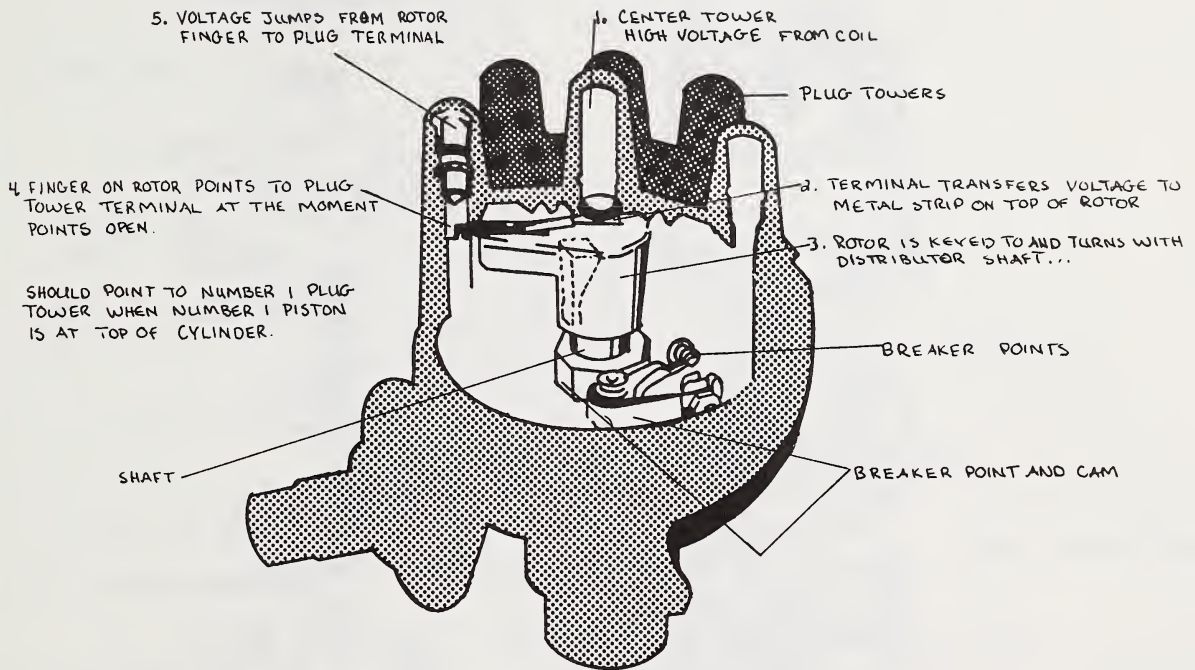
The ignition distributor performs three functions.

1. It opens and closes the primary circuit to produce the magnetic buildup and collapse in the ignition coil.
2. It delivers the high voltage surges from the secondary so they will be produced at the right time.
3. It delivers current to the proper plugs.

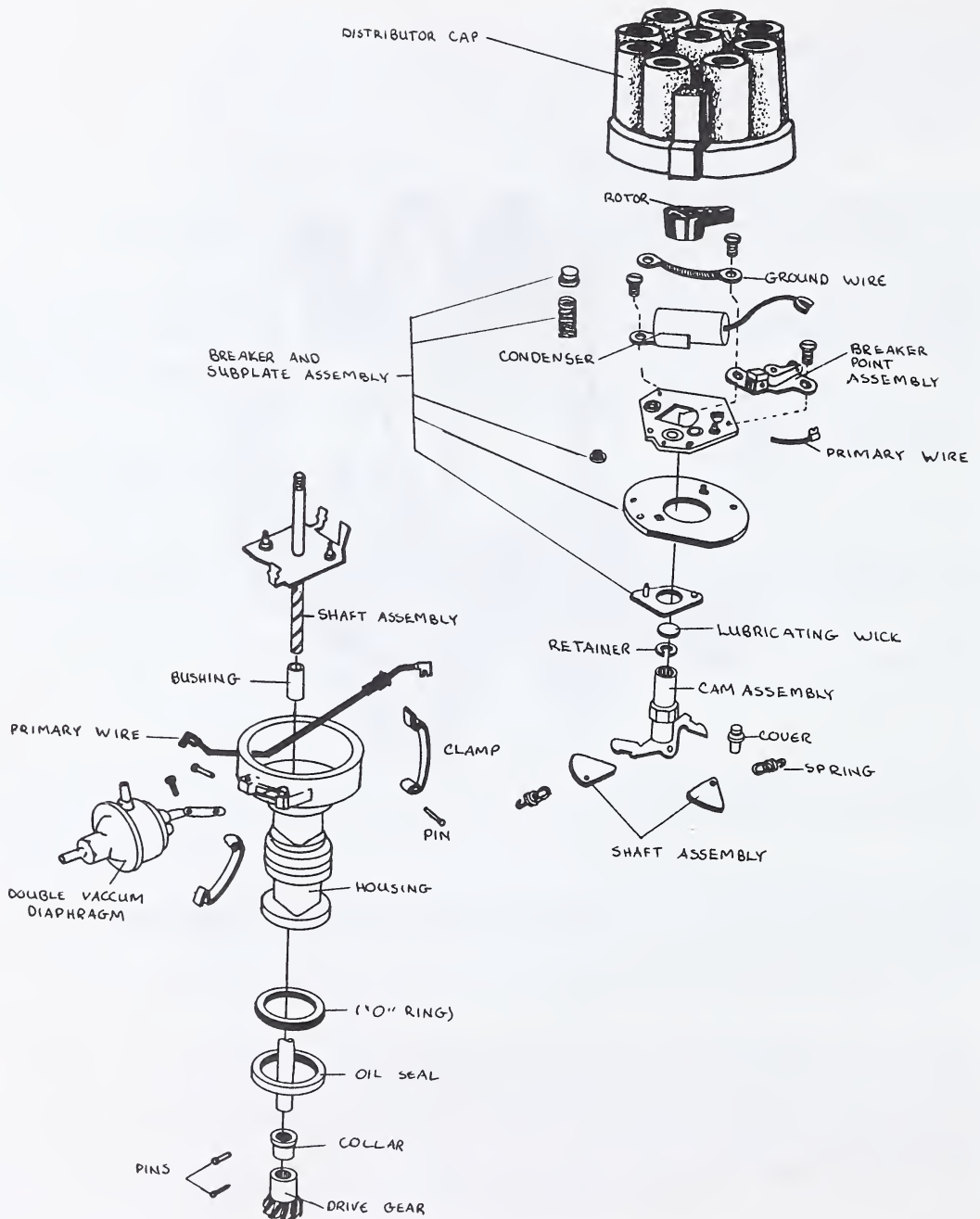
The major parts of the distributor unit include the distributor cap, rotor, distributor housing, breaker assembly, and distributor drive shaft. Diagrams on the following four pages indicate how these parts fit into the distributor.

The distributor cap is made from a molded plastic material which makes it a good insulator. Internal brass terminals are molded into the cap. These contacts are equally spaced around the cap and lead to the spark plug terminals (or plug towers) in the top of the cap. The centre cap terminal (or center) connects to the high tension cable from the coil. The cap is notched into the housing to prevent incorrect installation.

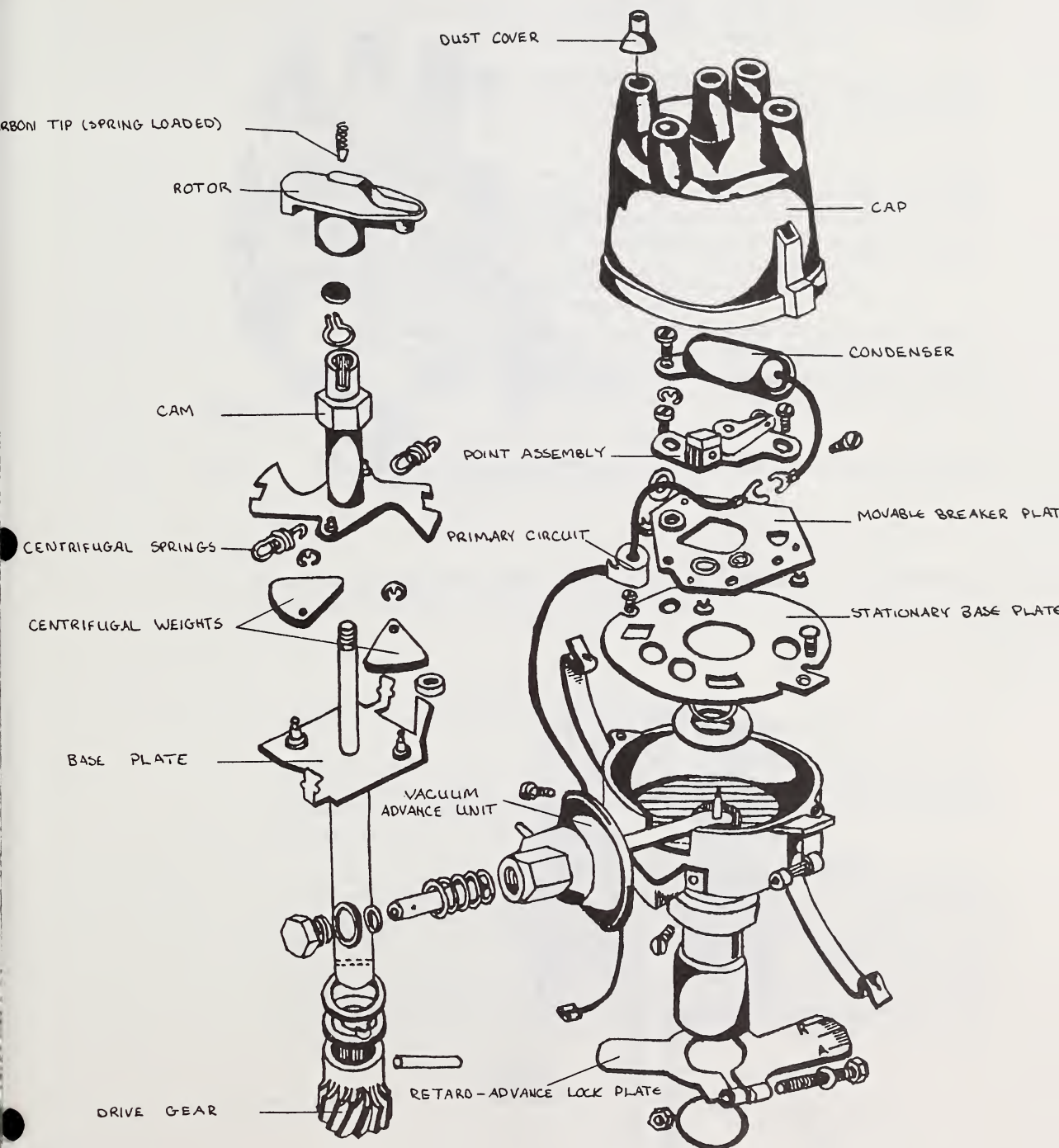
The rotor is also made from molded plastic material which makes it a good insulator. The rotor mounts on top of the drive shaft directly above the upper part of the breaker cam. A flat side of the rotor hub fits on a flat side in the cam. This ensures the rotor has a positive drive and exact alignment. On the top of the rotor a spring metal tab is in contact with the distributor cap's centre terminal. A solid metal piece completes the circuit to each spark plug terminal in the cap as the rotor turns. There is relatively no resistance to the flow of the high-voltage current.

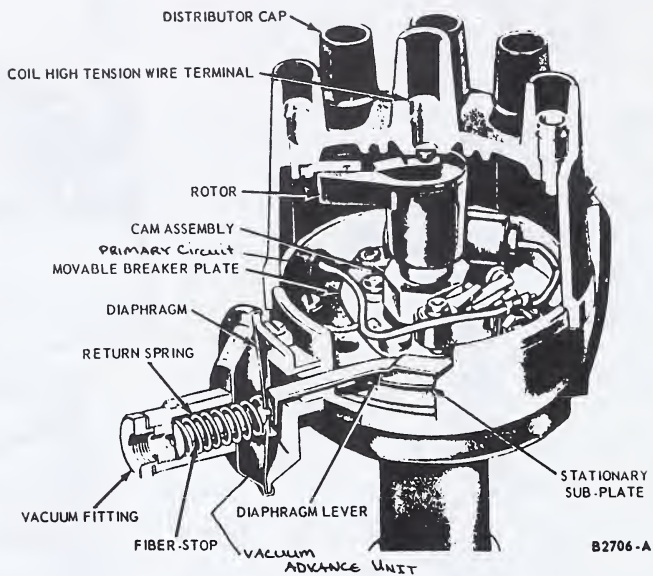


How the distributor cap and rotor work together

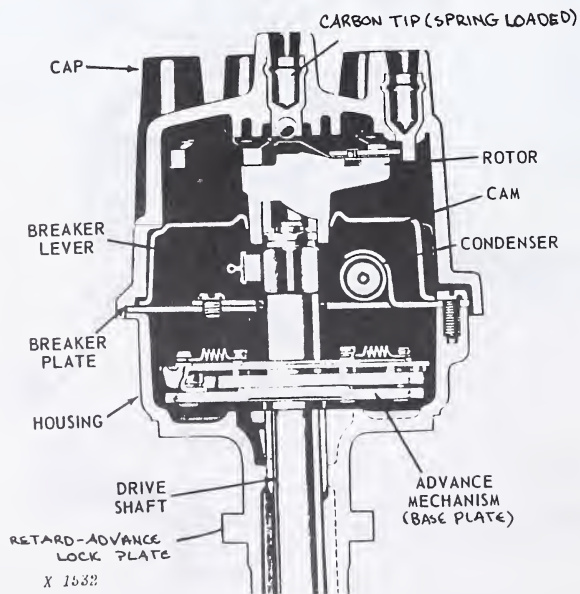


Parts in a contact type ignition distributor





*Courtesy of Ford Motor Co.*



*Courtesy of John Deere Ltd.*

The distributor housing contains the distributor drive shaft, breaker assembly, and ignition advance assembly. The housing provides a container for the distributor parts to be firmly attached to and also protects these parts from dirt and water. The distributor cap fits into the top of the housing and is firmly clamped into place.

The distributor drive shaft is driven by the engine camshaft through a drive gear. The drive shaft is driven at one-half engine or crankshaft speed. The shaft operates the centrifugal advance mechanism (described later) plus the breaker cams and rotor.

The breaker assembly or mechanisms comes as a complete unit. It is composed of a stationary base plate upon which a movable breaker plate is attached. The breaker plate is used for mounting the contact points (breaker points) and condenser. It also has a terminal which connects the points and condenser to the primary circuit. By loosening one or two screws the stationary portion of the point assembly is moved on the breaker plate. This is the procedure for adjusting the point gap.

The breaker cam is mounted on the upper end of the distributor drive shaft and is connected to the centrifugal advance. (See the centrifugal advance section later in this lesson for a diagram.) The cam has one lobe for each engine cylinder. As the cam rotates, the cam lobes move around under the contact arm, causing the contact points to open and close.

There will be slight differences in construction from one type of distributor to another, but they all operate on the same general principle.

**The distributor unit is one of the most important parts of the car and must be kept in excellent condition, to very fine specifications.**

#### **4. Wiring in the Primary and Secondary Circuits**

In the primary circuit of from 16 to 20 gauge is used since only relatively low currents produced by the battery are used. The wire is usually plastic insulated and composed of fine strands of copper wire interwoven for strength. Crimp-on or soldered connectors are used on the ends of the wire.

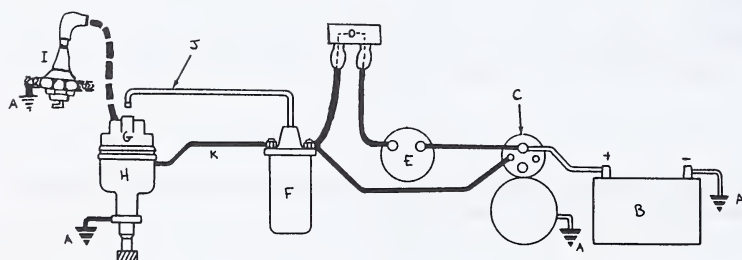
In the secondary circuit wiring must be used which can carry induced coil voltages (of more than 20 000 volts) from the coils high tension terminal to the distributor cap and also from the distributor cap terminals to the individual spark plugs. Due to the high voltages involved the secondary circuit wiring must be heavily insulated. Since the wires run close to the engine and exhaust manifolds they must also be heat resistant. The engine itself usually has oil, grease, and grime on it so the wiring must be oil resistant. The ends of the secondary wiring are usually equipped with special insulating "boots." These boots fit over the spark plug terminals, distributor cap terminals, and coil tower.

The core of the spark plug wires has changed greatly over the past thirty years. Until about 1965 the core was made of 16 gauge copper or aluminum. At that time carbon impregnated cores were developed to provide a resistance path for high voltage surges which helped reduce radio interference from the ignition system. In recent years graphite insulated fibreglas cores and soft silicone insulation have been introduced. These types of wire withstand more heat than earlier types and are also more durable.

#### (a) Ignition or ballast resistor

In many vehicles with 12 volt systems there is an ignition (or ballast) resistor placed in the ignition coil primary circuit. This resistor is connected in series between the ignition switch and the primary positive terminal of the coil. The function of this resistor is to protect the breaker points during low-speed operation when the points are exposed to burning caused by excessive current.

When the ignition switch is turned to the **start** position the ballast resistor assembly is bypassed from the ignition primary circuit. This allows maximum battery voltage to be provided to the ignition coil while the starter motor is drawing voltage from the battery.

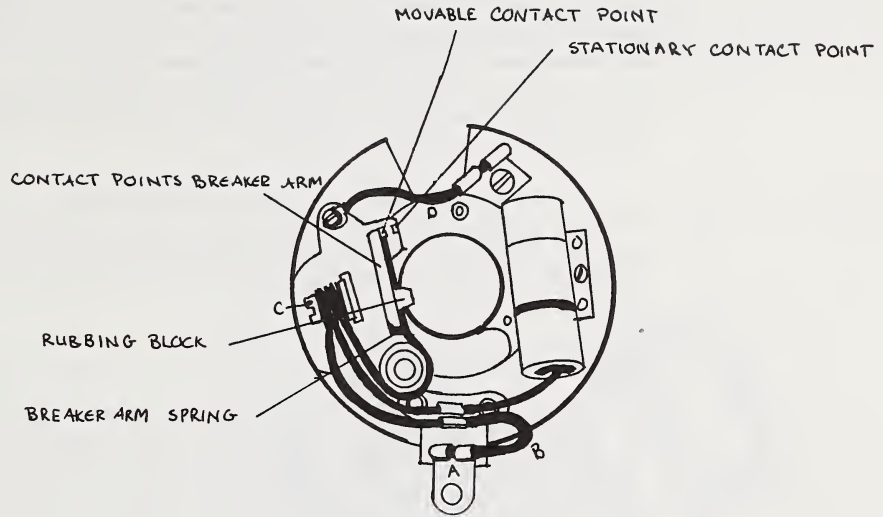


- A - Ground
- B - Battery
- C - Starter Relay
- D - Ballast Resistor
- E - Ignition Switch
- F - Ignition Coil
- G - Distributor Cap
- H - Distributor Base
- I - Spark Plug
- J - Secondary Circuit
- K - Primary Circuit

*Courtesy of John Deere Ltd.*

### 5. Breaker Plate Operation

As was mentioned earlier, the condenser is an integral part of the distributor and is mounted on the movable breaker plate. The wire leading from the condenser is attached to an insulated terminal on the breaker plate (ignition points). The outer case of the condenser is grounded. All wire insulation must be in good condition for it to function properly.



Breaker plate and parts mounted thereon

The current flow through a breaker assembly would normally be as follows. Current from the battery is delivered to terminal A which is on a flat insulated bracket outside the distributor. It is usually covered by a rubber grommet to prevent dust and moisture from entering the housing.

The current then flows through the wire to terminal C which consists of another insulated bracket mounted on the breaker plate. The contact points breaker arm is mounted in such a way as to be completely insulated from the rest of the distributor. This is done by having it ride on a non-conducting bushing. As well the rubbing block which contacts the cam is made of the same material. There is usually a clip on terminal C which holds the breaker arm spring and its copper conductor (if there is one). The current flows through the spring (or copper strip if there is one) around the arm to the movable point. When the points are in contact current can flow into the stationary point.

Current flows only in a closed circuit, therefore current stops immediately when the movable arm breaks contact of the two points (even though it is a very small gap that is created). From the contact points the current can flow into the movable breaker plate. A ground wire D then carries the current from the movable breaker plate to the stationary base plate which in turn is grounded to the distributor base.

Most point sets are held in place by a lock screw and also have an adjusting screw which sits in a hole the size of the screw head. This head is about 1.3 mm off center from the center of the screw thread. If the lock nut is loose and you turn the eccentric screw it can move the breaker points in or out by 1.3 mm. This gives an overall point gap adjustment of 2.6 mm which is much more than is ever needed. When adjusting point gap remember **turn the screw slowly** as the adjustment will occur quickly. The normal gap for the points is between 0.38 and 0.56 mm for most standard cars. Points are usually set to within  $\pm 0.02$  mm.

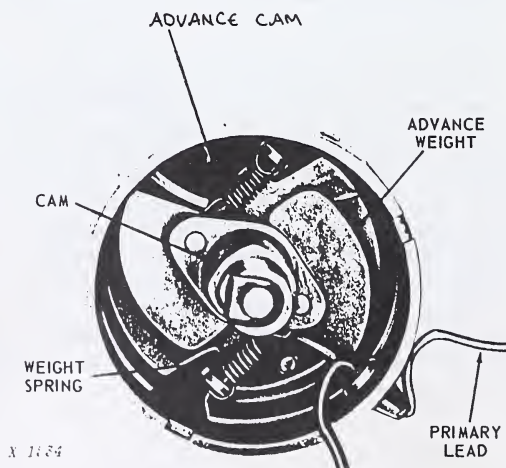
This is just a general overview of adjustment procedures. If in doubt always consult a service manual for the make and model of vehicle that you have. In some cases you may run into distributors that can be adjusted externally from the housing. There are also some distributors on the market that use two sets of points instead of only one set.

## 6. Spark Advancing

Advancing the ignition systems spark is required so that the spark will occur in the combustion chamber at the proper time in the compression stroke. At high speed the spark must appear earlier so the fuel-air mixture will have time to burn and give up its energy to the piston. At part throttle, when the fuel-air mixture is less highly compressed, a spark advance is required to ignite the slower burning mixture in ample time for it to burn and deliver its power. Centrifugal and vacuum advance mechanisms produce these advances.

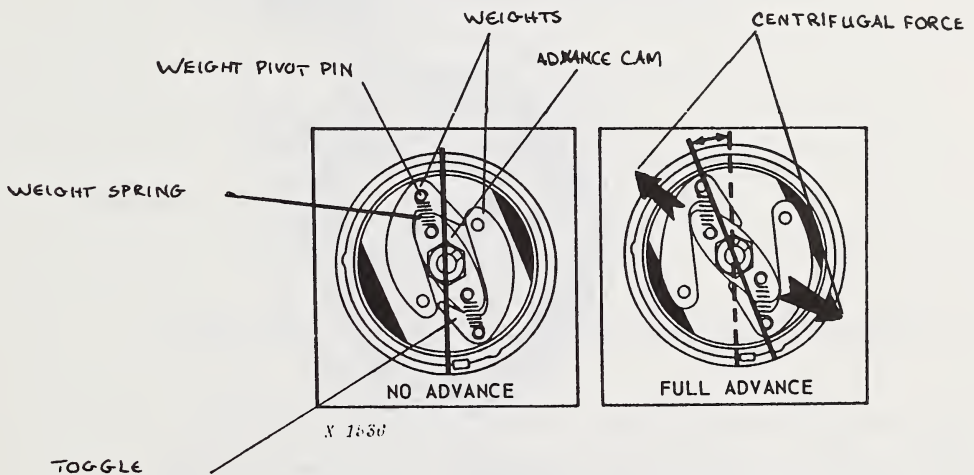
### (a) Centrifugal Advance

The centrifugal advance mechanism is located in the distributor housing and consists of a pair of weights mounted on pins on a weight base and linked by weight springs to the advance cam.



*Courtesy of John Deere Ltd.*

When idling, the springs hold the advance cams in a "no-advance" position. As engine speed increases the centrifugal force on the weights causes them to move outwards. This action forces the toggles on the weights to move against the advance cam so the cam is pushed ahead against the spring tension. As the advance cam turns ahead, the breaker cam lobes open and close the contacts earlier in the cycle. This advances the spark.



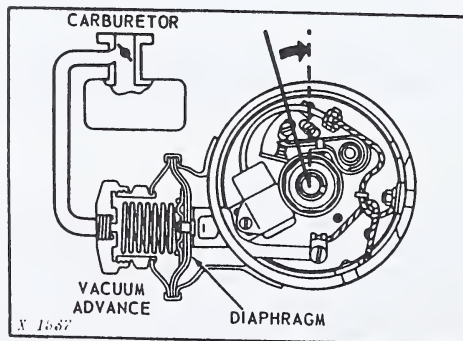
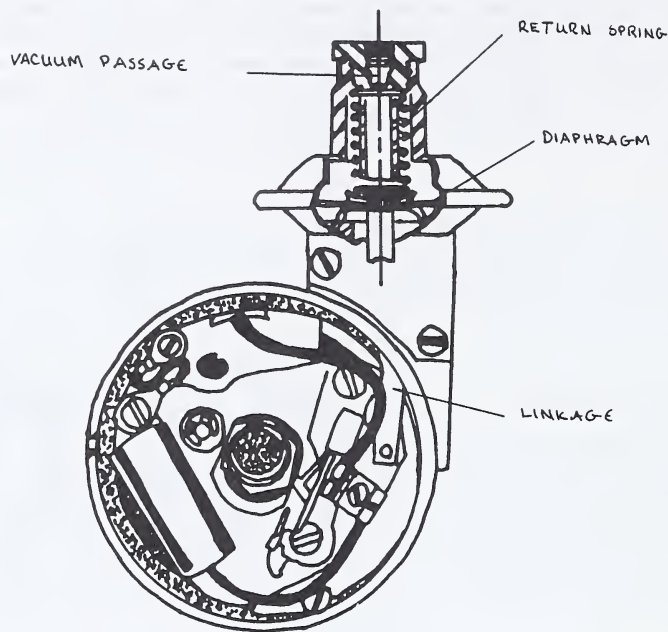
*Courtesy of John Deere Ltd.*

The centrifugal advance is zero when the engine is idling. It usually starts to advance at about 800 rev/min and advances steadily as engine speed increases until the maximum is reached. The maximum advance can vary considerably on the different makes and models of vehicles. The range is roughly from 18 to 40 crankshaft degrees. The engine speed at which maximum advance occurs can vary anywhere from 2400 to 4200 rev/min, depending on the make and model of engine.

#### (b) Vacuum Advance

Maximum engine torque at any given engine speed is obtained when the spark is advanced close to the point where pinging occurs in the cylinders. This pinging occurs only on an open throttle. On partial throttle, improved efficiency can be obtained by advancing the spark further than is provided for by the centrifugal advance system. This extra advance is provided by a vacuum-operated device.

The vacuum advance uses a spring-backed air-tight diaphragm connected to a vacuum opening in the carburetor via a vacuum line. The diaphragm is connected by a linkage so that it can rotate either the breaker assembly or the entire distributor. The diagram on the next page shows how a linkage is connected so the breaker plate can be rotated.

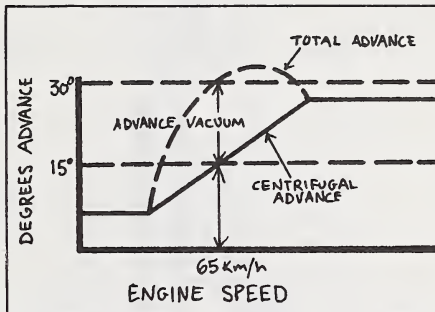


*Courtesy of John Deere Ltd.*

A vacuum at the intake manifold draws air from the diaphragm chamber. The return spring holds the diaphragm in the no-advance position until there is sufficient vacuum acting on the diaphragm to move it by overcoming the spring pressure. Movement of the diaphragm moves the linkage which in turn rotates the distributor breaker plate in the opposite direction of drive shaft rotation. The contact points meet the lobes of the breaker cam sooner and therefore spark is advanced.

If one looks at a carburetor, the vacuum part is located just above the throttle plate assembly when the throttle plate is closed and the engine is idling. However, as soon as the throttle plate is opened a little, the edge of the plate comes above the vacuum port and therefore the engine vacuum acts on the diaphragm.

A combination of the centrifugal and the vacuum advance mechanisms gives a spark advance unit which is sensitive to all speed and load conditions. Consider the following situation.



#### Centrifugal and vacuum advance curves for various engine speeds

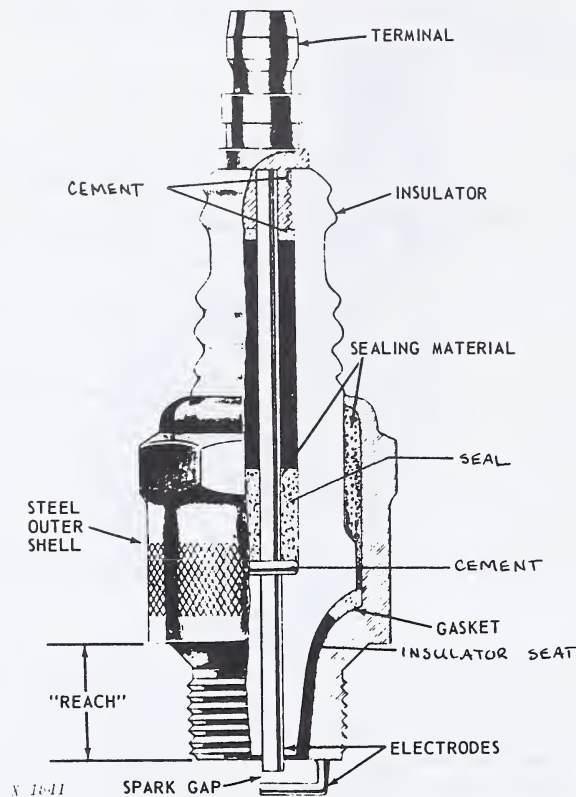
In a vehicle that has the above ignition advance curves note that there is no vacuum advance when the engine is at low speeds (such as at idle). As engine speed increases more vacuum is created by the engine. The vacuum advance unit starts to operate when about 20 kPa of vacuum is created. The centrifugal advance unit also starts to advance the timing as the engine speed is increased. At 65 km/h there will be 15° of vacuum advance and 15° of centrifugal advance.

As the engine speed increases further additional vacuum and centrifugal advance will be provided giving a total of 35° advance. As wide open throttle is approached the engine vacuum gradually drops and hence the vacuum advance decreases. Only centrifugal advance is used at wide open throttle (to reduce pinging).

### 7. Spark Plug

A spark plug consists of a center electrode which is insulated from an outer shell by a ceramic insulator such as porcelain. A side electrode is fastened to the spark plug shell which is in turn grounded to the engine's cylinder head. A space, called a spark gap, exists between the two electrodes. This gap ranges from 0.5 mm to 1.0 mm depending on usage and specifications.

Spark plugs have the simple purpose of supplying a fixed gap in the cylinder across which the high voltage surges from the coil must jump.

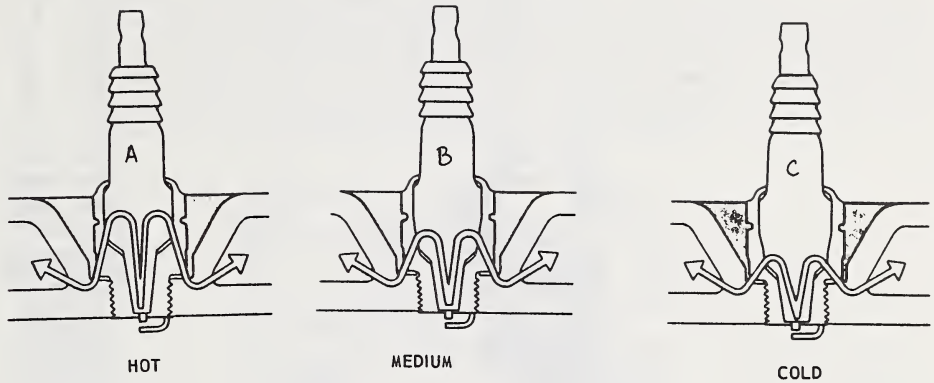


*Courtesy of John Deere Ltd.*

A high-tension wire from the distributor is attached on the top of the center electrode. Current flows down the center electrode, jumps the gap to the side electrode (arcs across) and thus creates a spark which ignites the fuel-air mixture in the combustion chamber. Most of the spark plugs in use today are between 10 and 18 mm in thread diameter. They also come in many different lengths and it is therefore imperative that the proper plug is always used in an engine.

Spark plugs are also made in several heat ranges so that there is a suitable plug for any given engine for different operating conditions. For example, at continuous high-speed driving a very cold plug is desirable, while the slower operating vehicle requires a hot plug. A plug that runs too cold will accumulate heavy coatings of carbon (unburned gasoline) while a plug that runs too hot will soon burn up.

It must be remembered that the interior of a combustion chamber is exposed to heat in the area of  $2\,500^{\circ}\text{C}$  at the beginning of the power stroke, when operating at full throttle. However, the melting point of iron is only  $1\,400^{\circ}\text{C}$ , so this excess heat must be dissipated as fast as possible, to prevent the engine from seizing up. The heat that is thus absorbed by the plug is conducted into the cylinder head as shown on the next page.



*Courtesy of John Deere Ltd.*

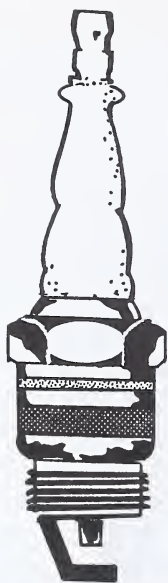
The longer the heat takes to dissipate from the plug (the longer the path for the heat to travel) then the hotter the plug will operate at. In the drawings above C is a much colder operating plug since the path is shorter and heat can escape more readily.

By conducting heat to the cylinder head the nose of the plug is kept within an operating temperature so that the electrodes are not melted or worn away by the hot flame. As well, the insulator remains undamaged.

The hottest part of the plug is the tip of the nose. Heat flows up through the plug as shown by the arrows. Hot and cold plugs have the same outer appearance. The only difference is the length of the path for heat to flow from the centre electrode to the cylinder head.

A cold plug is recommended when a car is to be driven on an open throttle most of the time. This helps to dissipate the heat faster. Slow driving with these plugs will foul them up somewhat, but not enough to hinder the operation (as long as there are periods of high speed operation to burn them clean). The opposite is true about hot plugs. If used in an engine at high speed for a considerable length of time hot plugs will be damaged.

The spark plug gasket (usually a copper type washer) is a very important factor in conducting the heat from the plug to the cylinder head. If not torqued to a proper pressure it can seriously obstruct the flow of the heat. If the plug is too tight or too loose, the heat damage which results will greatly reduce the life and efficiency of the plug. **NOTE:** remember two plugs of the same size can have different heat ranges dependent upon thickness and type of material used which compensates for lengths.



Tapered Plug



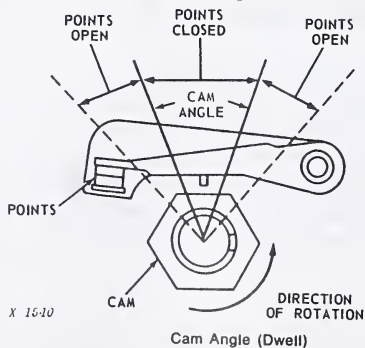
Gasket-type Plug

Some spark plugs do not need a gasket. In the drawing above, the plug on the left has a tapered seat which seals tightly against the plug hole in the cylinder head. No gasket is required. The plug on the right requires a gasket for sealing the plug against the cylinder head.

## ELECTRONIC IGNITION

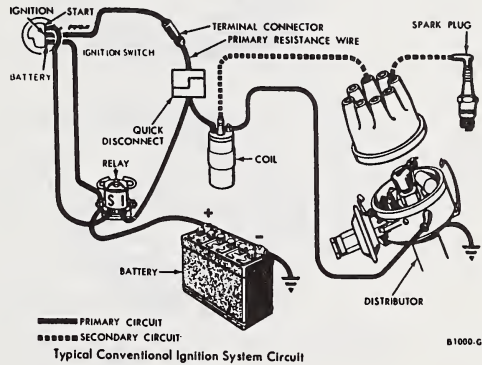
In a conventional ignition system current flows through the ignition coil primary and through the closed points to ground. This flow is interrupted when the breaker cam causes the breaker points to open. The magnetic field in the coil collapses, inducing a high voltage in the secondary, which fires the spark plug.

The time the points remain closed is called dwell or cam angle and is measured in degrees. Dwell will vary according to the point gap. The breaker point rubbing block wears slightly with each revolution of the breaker cam (breaker points open and close 16 000 times per minute with an 8 cylinder engine running at 40000 rev/min so the gap between the points continually gets smaller. This results in deteriorating engine performance and if not remedied engine misfiring and greater fuel consumption occurs.

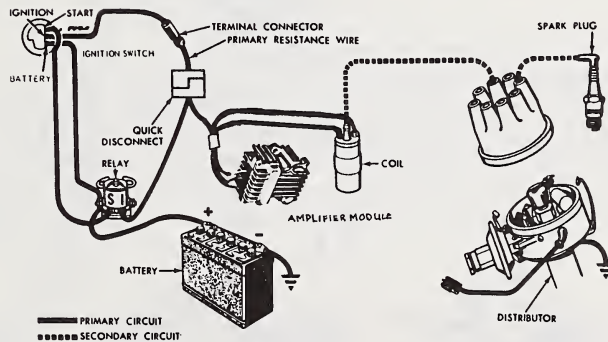


*Courtesy of John Deere Ltd.*

By using an electronic ignition one eliminates the parts that wear out in a conventional ignition system and replaces them with solid state devices. The distributor cam, breaker plate, points, and condenser in the conventional system have been replaced by an armature, pickup coil, and an electronic control module (amplifier). The rest of the ignition system (ignition coil, rotor, and high voltage wiring) is functionally unchanged except for the way in which some components are constructed.

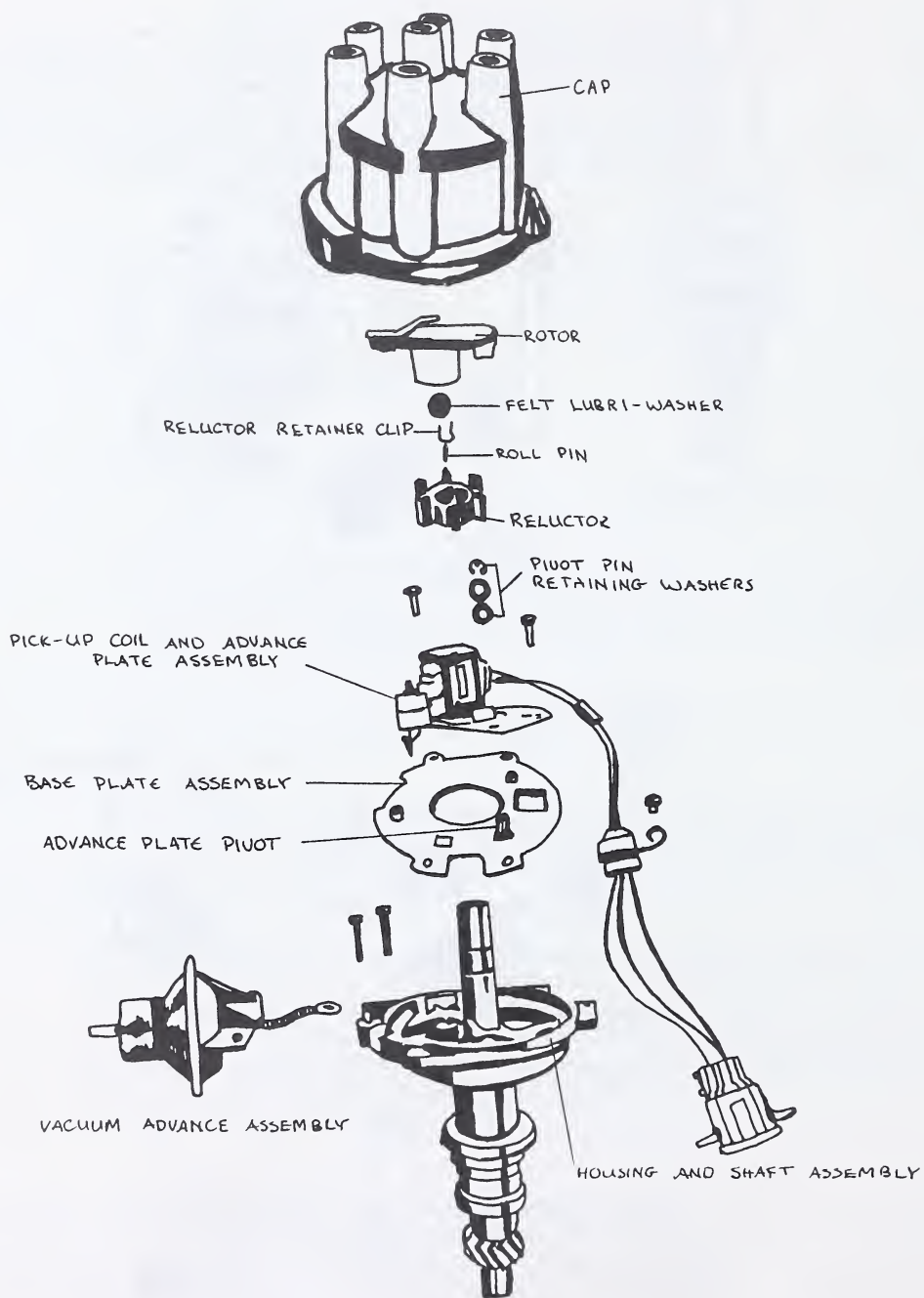


*Courtesy of Ford Motor Co.*

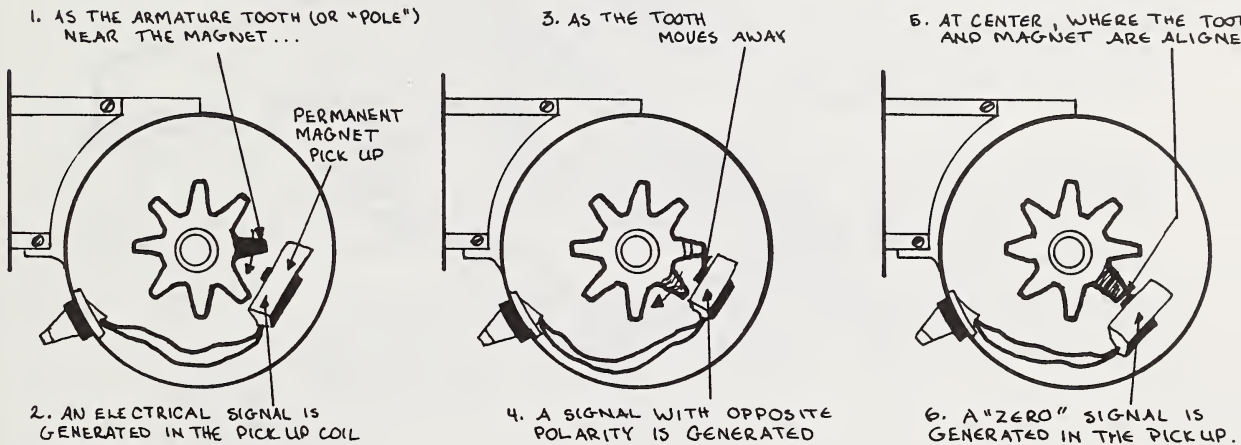


*Courtesy of Ford Motor Co.*

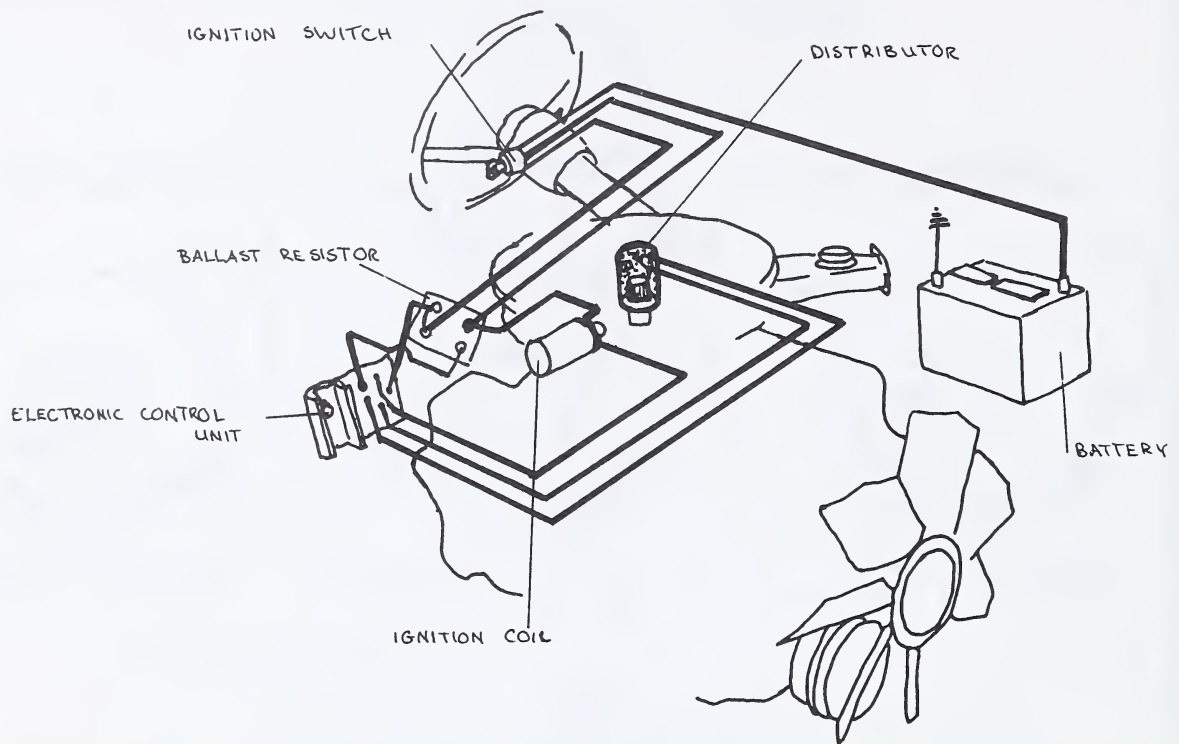
Electronic ignition systems require little maintenance, have longer durability, and are much more efficient than conventional ignition systems. By more efficient is meant more accurate control over ignition timing between normal tune up intervals. There is less misfiring and therefore better performance and greater emission control results.



In the electronic ignition system a toothed gear on the distributor shaft (called a reluctor) replaces the breaker cam and rubbing block. The reluctor rotates close to (but not touching) a permanent magnet in the pickup unit.



As the reluctor rotates past the pole piece on the pickup coil, it causes a rapid change in magnetic field which induces a timing pulse in the pickup coil. This current pulse going to the control unit causes the transistor switch in the control unit to open and interrupt the primary current in the ignition coil. High voltage is induced in the secondary and a spark occurs at the spark plug. The length of time that current in the ignition coil is interrupted is determined by the control unit. Thus the dwell (or cam angle in the conventional ignition system) is "built-in" and is always correct unless the control unit is faulty.



### Location of Components In a Typical Electronic Ignition System

Students should be aware that this lesson presents basic information on electronic ignition systems. Variations in construction, maintenance, and operation occur among vehicle manufacturers. For more complete information consult the shop manual for the vehicle you are working on.

### COMPUTER CONTROLLED IGNITION TIMING

Starting in the early 1980s vehicle manufacturers determined that more precise control of ignition timing was required in order to improve engine performance, increase fuel economy, and give better emissions control. Some manufacturers used electronic ignition timing and electronic fuel metering systems to achieve improvements. However more increases were wanted. After much experimentation manufacturers are now using a variety of control units which manage an engine's spark, fuel, and emissions. These control units are composed of sensors, relays, activators, and solenoids which are operated by an electronic engine control computer (EEC) or a micro processor control computer unit (MCU).

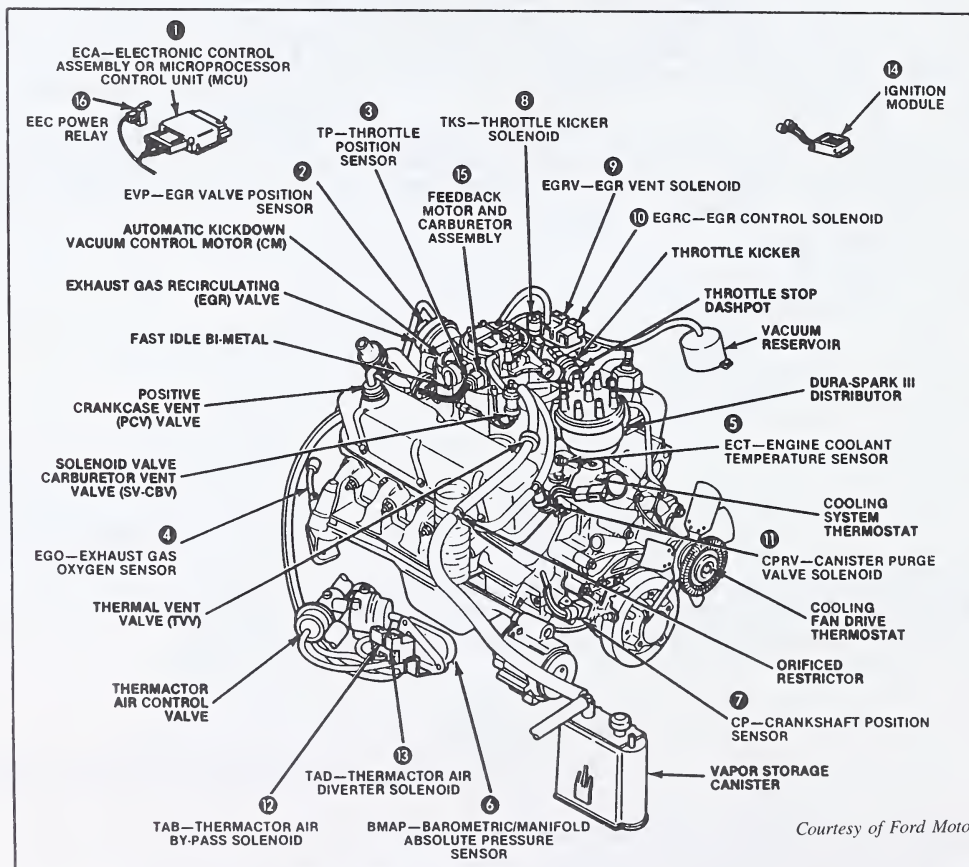
Sensors are placed within various areas of an engine. These sensors pick up various data relating to engine operating performance and send a "signal" to the computer. The term "signal" is used to describe the delivery of very low voltage through electrical wiring to or from an electrical device. Input signals are "read" by the computer and from the information it receives, the computer sends an output signal to a relay, switch, or activator which adjusts the ignition timing.

It is important to remember that relays, switches, and activators can only operate by commands given by the computer. They do not begin to function until they are told what to do. These commands are built into the electronic circuitry within the computer. This is known as "programming." Engineers program the computer depending upon the engine, transmission, axle ratio, and accessories available.

The computer is used to vary ignition timing based on changes in engine speed, load, temperature, barometric pressure, and a variety of other factors. Remember that the computer receives data from sensors, analyzes these readings based on its programming, and then sends instructions to the various control units.

It is beyond the scope of this course to go into details of various ignition timing controls that are available, however, the following drawing (which covers the various engine controls of a late 1980s Ford V-8 engine) will give students an idea of the complexity involved.

## TYPICAL ENGINE CONTROLS ON A FORD V-8 ENGINE



*Courtesy of Ford Motor Co.*

**SUMMARY**

It must be remembered that in this lesson you have studied conventional and electronic ignition systems in a most basic and introductory way. The study of ignition systems at advanced levels is covered in other courses. Some vehicles have no ignition system at all. Diesel engines do not have spark plugs because the fuel is injected into a hot, highly compressed air mixture where it ignites due to heat and pressure.

The latter part of the 20th century will see great strides being taken on experimentation into changes of the ignition system as well as other areas of the automobile. This is because with the increased cost of fuel, we will be striving for more efficient means of using our fuel to get great mileage from the vehicle. This can be done by changing the fuel system, ignition system or the entire power plant system of the automobile. Advances are made in all areas each year and it would be impossible for us to keep up with them here, but the general method of obtaining the end result remains the same. To operate the internal combustion engine we must get the fuel to the cylinders at the correct time and then ignite it at precisely the correct time for efficient operation.

Magazines such as *Popular Science* and *Mechanics Illustrated* are good references for people who wish to keep abreast of the changes that are taking place in ignition and other vehicle systems.

Answer the following Self-Correcting Exercises. Check your answers with those listed at the end of this lesson.

**SELF-CORRECTING EXERCISE 1**

Choose the best answer for each of the following questions.

- \_\_\_\_\_ 1. Self induced voltage in the primary winding of an ignition coil is absorbed by the
- (a) wires.
  - (b) battery.
  - (c) distributor.
  - (d) condenser.
- \_\_\_\_\_ 2. The centrifugal advance mechanism controls spark timing by sensing engine
- (a) temperature.
  - (b) power.
  - (c) speed.
  - (d) oil pressure.

- \_\_\_\_\_ 3. A spark plug
- (a) increases the spark intensity.
  - (b) controls the spark timing.
  - (c) produces the voltage to fire the air-fuel mixture.
  - (d) provides a gap for the spark to jump across.
- \_\_\_\_\_ 4. What determines the heat range of a spark plug?
- (a) engine torque
  - (b) the number of cylinders
  - (c) engine design and operating conditions
  - (d) whether the engine is a two stroke or four stroke
- \_\_\_\_\_ 5. The ignition coil produces high voltage surges when the magnetic field
- (a) increases.
  - (b) decreases.
  - (c) holds steady.
  - (d) is at its minimum value.
- \_\_\_\_\_ 6. Wiring in the secondary circuit of a conventional ignition system must be
- (a) heat resistant.
  - (b) oil resistant.
  - (c) heavily insulated.
  - (d) all of the above.
- \_\_\_\_\_ 7. Spark plug wires used in modern cars have a core that is composed of
- (a) solid copper wire.
  - (b) stranded aluminum wire.
  - (c) impregnated carbon.
  - (d) fibreglas with graphite insulation.
- \_\_\_\_\_ 8. The parts of a conventional ignition system that have been replaced by solid-state devices in an electronic ignition system include
- (a) the breaker plate.
  - (b) the distributor cam.
  - (c) the points.
  - (d) all of the above

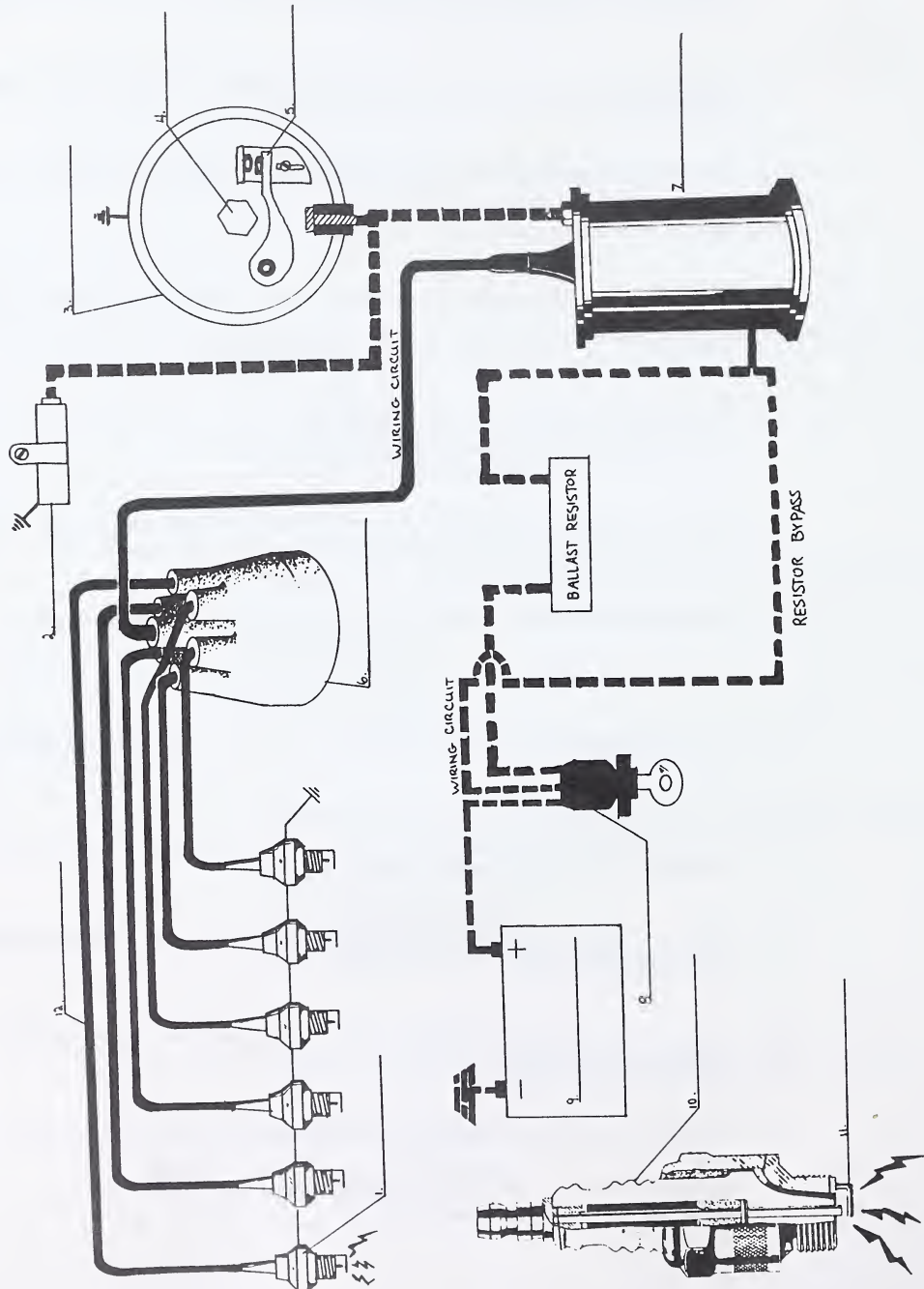
**SELF-CORRECTING EXERCISE 2**

Fill in the blanks of each of the following statements with the best word or words.

1. A \_\_\_\_\_ is used in conjunction with a centrifugal advance mechanism to improve spark timing.
2. \_\_\_\_\_ is the term used to indicate spark plug operating temperature.
3. Dwell may be defined as the number of degrees of breaker cam rotation when the points are \_\_\_\_\_.
4. The primary ignition circuit includes the ignition switch, battery, primary coil windings, plus the \_\_\_\_\_ and condenser.
5. The secondary ignition circuit includes the \_\_\_\_\_, secondary coil windings and the rotor plus distributor cap.
6. The \_\_\_\_\_ is a cap on the distributor cam shaft which while turning makes and breaks the high voltage circuit to the correct spark plug lead.
7. The plate on which the condenser and points are mounted is called the \_\_\_\_\_ plate.
8. In an eight cylinder engine there would be \_\_\_\_\_ lobes on the distributor breaker cam.
9. The breaker cam pushed against the \_\_\_\_\_ on the contact point assembly in order to open the points.
10. The \_\_\_\_\_ of the distributor is the only mechanical connection to the internal workings of the engine.
11. \_\_\_\_\_ are used in order to create a tight seal between the spark plug and the engine cylinder head.
12. If current is flowing through the closed ignition circuit of a vehicle and the movable point arm breaks contact between the contact points then \_\_\_\_\_ flow stops immediately at that point.

## SELF-CORRECTING EXERCISE 3

Label the parts indicated in the following drawing of a conventional ignition system.



Please complete the following exercises and send them in for correction.

**EXERCISE 1****Short Answer**

1. What is the purpose of having an ignition system?

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2. What occurs in the ignition coil when the points open?

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3. Why is the core of an ignition coil composed of laminations of iron rather than one solid piece?

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4. Why does the ignition system of an automobile use a combination of centrifugal advance and vacuum advance?

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5. What would happen to the spark plug of an engine that required a "hot" plug and a "cold" plug was used instead?

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6. In an electronic ignition system what part (or parts) replace the breaker plate assembly?

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7. How does the reluctor cause a spark to be induced in the secondary of an electronic ignition system?

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8. What is the function of an activator in a computer controlled ignition system?

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9. What three jobs must the distributor perform?

(a) 

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(b) 

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(c) 

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10. A coil with a secondary winding of 40 000 turns has a primary winding of 400 turns. The voltage in the primary circuit is 120 V. What will be the induced voltage in the secondary? Show your work.

**ANSWERS TO SELF-CORRECTING EXERCISES****Self-Correcting Exercise 1**

- |                |                  |
|----------------|------------------|
| 1. d (page 8)  | 5. b (pages 3-5) |
| 2. c (page 17) | 6. d (page 13)   |
| 3. d (page 19) | 7. d (page 14)   |
| 4. c (page 20) | 8. a (page 1)    |

**Self-Correcting Exercise 2**

- |                                 |                              |
|---------------------------------|------------------------------|
| 1. vacuum advance (pages 17-19) | 7. movable breaker (page 13) |
| 2. Heat range (pages 20-21)     | 8. eight (page 13)           |
| 3. closed (page 22)             | 9. rubbing block (page 15)   |
| 4. contact points (page 1)      | 10. shaft (page 1)           |
| 5. spark plugs (page 1)         | 11. gaskets (page 22)        |
| 6. rotor (page 8)               | 12. current (page 15)        |

**Self-Correcting Exercise 3 (pages 2-4)**

- |                               |                          |
|-------------------------------|--------------------------|
| 1. spark plug                 | 7. coil                  |
| 2. condenser                  | 8. key switch            |
| 3. distributor case (housing) | 9. battery               |
| 4. cam                        | 10. spark plug porcelain |
| 5. points                     | 11. ground electrode     |
| 6. distributor cap            | 12. spark plug wire      |



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